Micro Grid Reliability Improvement Based On Smart Grid Techniques

M. A. A. MEHANNA, M.F. ABD ELAZIZ OMAR
Department of Electrical Engineering, Faculty of Engineering, Al-Azhar University, Cairo, Egypt.
Mehanna2002@hotmail.com , Mfomar80@gmail.com

Abstract- The electric utilities now a day in the way of modification from the traditional grids to smart grid. This modification improves in high significant action the reliability indices. Smart meter is considering one of the major component in smart grid. As smart meter improves the most important characteristic of smart grid which is the accurate and fast communication between grid component. This quick, and accurate information between grid component support the quick action needed to improve grid reliability specially both of the customer base indices, and the energy base indices. This paper will introduce how smart grids decrease the outage time and load, which reflect on SAIDI, CAIDI, ENA, and AENS indices. The paper will discuss two issues how smart grid affect the reliability indices over two different modules. First the impact of installing smart tools in conventional grid, which consist of commercial and residential loads. Second the load shedding technique within an existing smart grid of commercial loads, how this technique uses the spare generation power, and maintain system stability.

Index Terms— Smart Meter, Smart Grid, System average interruption duration index, Customer average interruption duration index, Energy not supplied, Average energy not supplied, Mean time to transfere switch, Mean time to repair, Operation Technology, Information Technology, Automated Feeder Switching, Fault Location Identification and System Restoration(FLISR), Power Management System(PMS)

1 Introduction

Now a day's utilities make an evolutionary change in the electricity infrastructure, and smart grid(SG) may hold that key of modernization and realization in grid [8]. So the main factors affect the decision of this revolution in changing the mind from traditional grid to smart grid is, how much there will be reliability improvement [4]. The goal for any utility that invests in smart grid technology is to attain higher efficiency and reliable performance [3]. A smart grid platform implies the convergence of Operations Technology (OT) – the grid physical infrastructure assets and applications–and Information Technology (IT) – the human interface that enables rapid and informed decision making. This paper describes best practices for migrating to a scalable, adaptable, smart grid network. [1,4]

In other word the Smart Grid is transforming utility operations and pushing IT across its traditional boundary into OT at a remarkable clip, rapidly blurring the distinction between the two categories [1]. This paper discusses the dynamics of IT and OT integration and how utilities can leverage this convergence for smarter, more cost effective, and more reliable operation [8].

Reliability indices which will be focused in this paper could be divided into two categories. Customer Based Indices, and energy based indices [5]. Both of the two categories could be used to assess the past performance of the grid. As mentioned before and after using the smart grid tools. Smart grid tools used also to target the reliability indices improvement, which done by two ways minimize the outage time and minimize the outage loads [2,4].

This fast and accurate mutual information exchange between smart grid componenet could help in the load management as shown in the second experiment in this paper. Help in grid stability specially if it is in island mode of operation [1,2].

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 [3,7].**

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)

ISSN 2229-5518

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) $\sum(U_i x N_i)/\sum N_i$ (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(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) [6,7]

3- Installing Smart Grid Component in Conventional Grid to Minimize Outage Time

Using Smart meters is one of the major benefits of investing in smart grid technologies, tools, and techniques include faster utility responses to power outages and the ability to restore services more quickly compared to traditional outage management techniques. Traditional distribution grid could be converted to micro grid in brief by the following steps.

First Distribution automation, including automated feeder switching (AFS) and fault location isolation, and service restoration (FLISR). The utilities that use AFS for FLISR operations are improving their electric reliability indices such as CAIDI and SAIDI and helping to improve grid reliability.

Second Integrating Advanced Metering Infrastructure (AMI). Where there will be comparison in the outage time over two case of study. First the repaire time including (repaire time + fault location identification) in conventional case(Fig1). where conventional grid over the medium voltage level (22K.V) with total loads(6.2MVA)

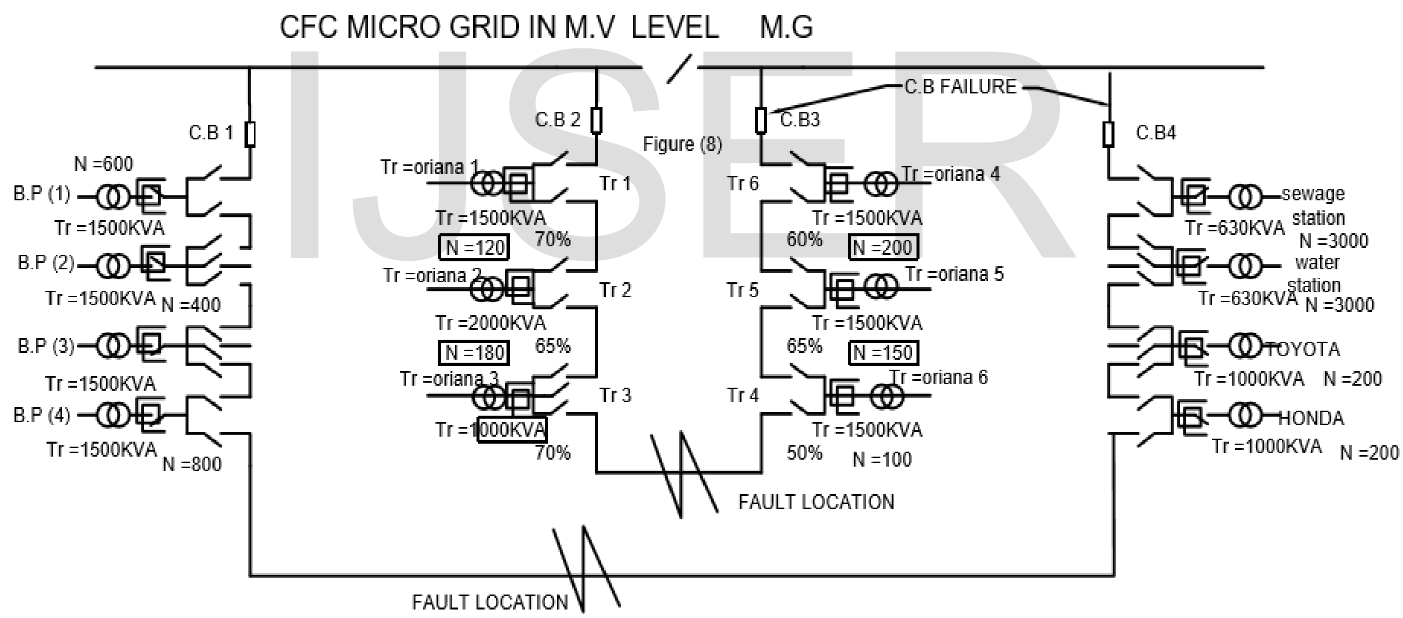

Fig.1 conventional grid without smart component installation

Second the repaire time (repaire time + fault location identification) after adding smart tools to conventional grid.

3.1 Conventional grid- (base case)
3.1.1 Grid description

*It is medium voltage level grid consist of residential, commercial, and service loads.

* Number of person use this grid 8700

*Total load 6.208 MVA

*In this module there will be cable fault located between

ISSN 2229-5518

BP4 and Honda building

* According the normal procedures the Rt repaire time = Fault Location Identification+cable repaire time

* rt = FLISR (fault location identification & service restoration) (30 minute) + CRT (cable repaire time)
(120 minute) =2:30 hr

This is the traditional procedures followed by operation and maintenance team to identify the fault location:
Switch off CB no. 4
Switch off all L.B.S of all RMU connected to this loop
Begine to connect in cascading order each load starting from B. P1 till the sewage station.
Till trip occure again
There for the crew know the faulty zone and isolate, and continue feeding the rest of the loads.

3.1.2 Indices Computation Assumption

1-The period of MTTS (mean time to tranfere switch) between isolation of the loop from the main feeding of Micro grid and Gen. Startup individually for each building is nearly 5 min. (0.083 hr.)
2-The MTTR (mean time to repaire) the fault in the mentioned loop will be identified according operation procedure will be within 30min.
3-The repair time (Rs) could be calculated using this formula Repair TIME (rs)
= (MTTS. *gen%of load coverage) + (MTTR. *%of un covered loads)
4-Assume that Gen. (Failure per year f/yr.=5%) and percentage of Gen. reliability95%
5-Outage time= [rs*95%] + [MTTR*5%]
6-N is the no. of customers. Table (1) show the reliability indices values in this scenario. The (FLISR) will be 30 minute this is in addition to the main repaire time of the cable 2 hr.

Table 1 reliability indices calculation in base case- conventional grid

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	0.27362857	1050	1312.5	600	30	164.1771	359.1375
B.P2	80.00%	20.00%	0.1664	0.18308	750	937.5	400	20	73.232	171.6375
B.P3	66.67%	33.33%	0.222	0.2359	900	1125	500	25	117.95	265.3875
B.P4	50.00%	50.00%	0.2915	0.301925	1200	1500	800	40	241.54	452.8875
HONDA	61.54%	38.46%	0.243385	0.25621538	650	812.5	200	10	51.24308	208.175
TOYOTA	61.54%	38.46%	0.243385	0.25621538	650	812.5	200	10	51.24308	208.175
WATER STATION	0.5	0.5	0.2915	0.301925	504	630	3000	150	905.775	190.2128
SEWAGE STATION	0.5	0.5	0.2915	0.301925	504	630	3000	150	905.775	190.2128
					6208		8700	435	2510.935	2045.826
	SAIDI		0.288613							
	CAIDI		5.772265							
	ENS		2045.826							
	AENS		0.235152							

3.2 Installation of smart tools.

3.2.1 Steps of conversion to smart grid

In this case traditional grid changed to smart by the following action:
Modify all the L.B.S(load break switch) to be motorized and provided with auto reset circuit
There will be P.T (potential transformer) &C. T (current transformer) installed over the cable head connected with the R.M.U(ring main unit)
There will be micro controller connected to the trip circuit and auto reset of each R.M.U
There will be main logic controller (auto reclosure) connected with smart meter installed at start & end of each loop.
All the data of each R.M.U (voltage, no. of switching, L.B.S address no., L.B.S status – on or off)
The communication between the smart meters could be used as data bus showing the following details:
Power flow
Losses of each Tr.
R.M.U switching information
Voltage profile (swelling and spikes, any partial discharge) early detection for any insulation failure
Complete current profile (indication for any harmonic effects, unbalanced loads, power factor, predicted no. of customers at this moment).

3.2.2 Indices computation basis and assumption after installing smart component

The time of fault location identification will be decreased from 30 min to 3 minute due to the following procedures as shown in fig.2.
All the R.M.U along the loop will be tripped off and begin to reclose automatically in cascading order, where the feeding will be through one side only let it C. B1

The R.M.U will be connected (reclosed- first reclose) one after the other (starting from B. P1 to sewage)
There will be time lag near to 3 second between each R.M.U switching and the other
Till connecting B. P4 instantenously C. B1 and all the R.M.U in this branch will be tripped.
By this way the fault will be identified by the first reclose that the fault is between B.P4 and HONDA
When C. B4 connected in the same action happened where the fault isolated and identified and all the smart meters will communicate showing the power flow directions

The presence of smart meter and due to the instantenous trip. The smart meter register the current value, and report back to stop the second reclose in the motorized LBS(load break switch). The second reclose will take action again over all LBS of all the loads in the loop except out-going(honda&BP4).
In this case the repaire time will be (MTTR of the cable(2 hr)+FLISR fault location identification (3 min)).=2:3 hr .Table (2) show the indices values after decrease the FLISR from 30 minute to 3 minute.

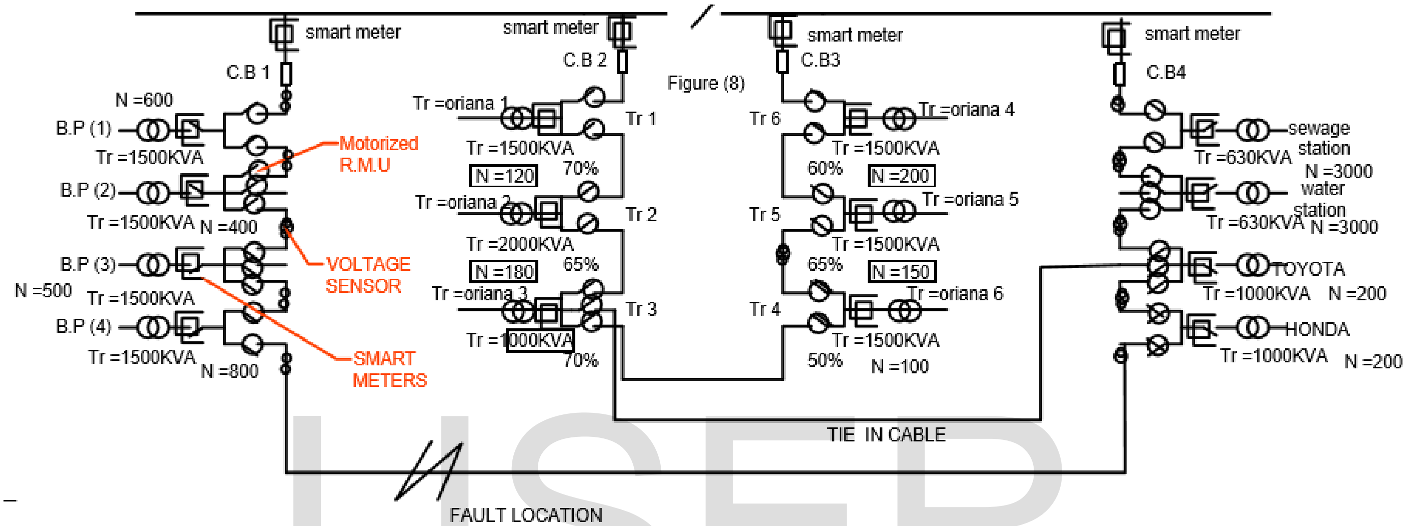

Fig. 2 installation of smart component (changed from traditional to smart)

Table 2 indices calculation after installing smart tools

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%	0.068857	0.06791429	1050	1312.5	600	30	40.74857	89.1375
B.P2	80.00%	20.00%	0.0764	0.07508	750	937.5	400	20	30.032	70.3875
B.P3	66.67%	33.33%	0.072	0.0709	900	1125	500	25	35.45	79.7625
B.P4	50.00%	50.00%	0.0665	0.065675	1200	1500	800	40	52.54	98.5125
HONDA	61.54%	38.46%	0.070308	0.06929231	650	812.5	200	10	13.85846	56.3
TOYOTA	61.54%	38.46%	0.070308	0.06929231	650	812.5	200	10	13.85846	56.3
WATER STATION	0.5	0.5	0.0665	0.065675	504	630	3000	150	197.025	41.37525
SEWAGE STATION	0.5	0.5	0.0665	0.065675	504	630	3000	150	197.025	41.37525
							8700	435	580.5375	533.1505
	SAIDI		0.066728							
	CAIDI		1.334569							
	ENS		533.1505							
	AENS		0.061282							

Table (3) show the improvement percentage after decrease the FLISR by smart tools from 30 minutes to 3 minutes. The improvement reach to 81% over customer base indices and 79% over energy sales based indices.

Table 3 Indices Improvement percentage after using Smart Tools.

reliability indices	SAIDI hr./customer yr	CAIDI hr./ customer interruptions	ENS KWh/yr	AENS KWh/ customer yr
Module 1 (CFC TRADITIONAL M.G)	0.363	7.272	2627.82	0.302
Module 2 (CFC SMART M.G)	0.067	1.334	533.15	0.0612
Percent of Improvement	81.54%	81.66%	79.71%	79.74%

Fig(3) show the indices values and the improvement percentage. How the usage of smart tools decreases the total repaire time by 27 minute. The improvement impact is high significant in both customer, and energy base indices

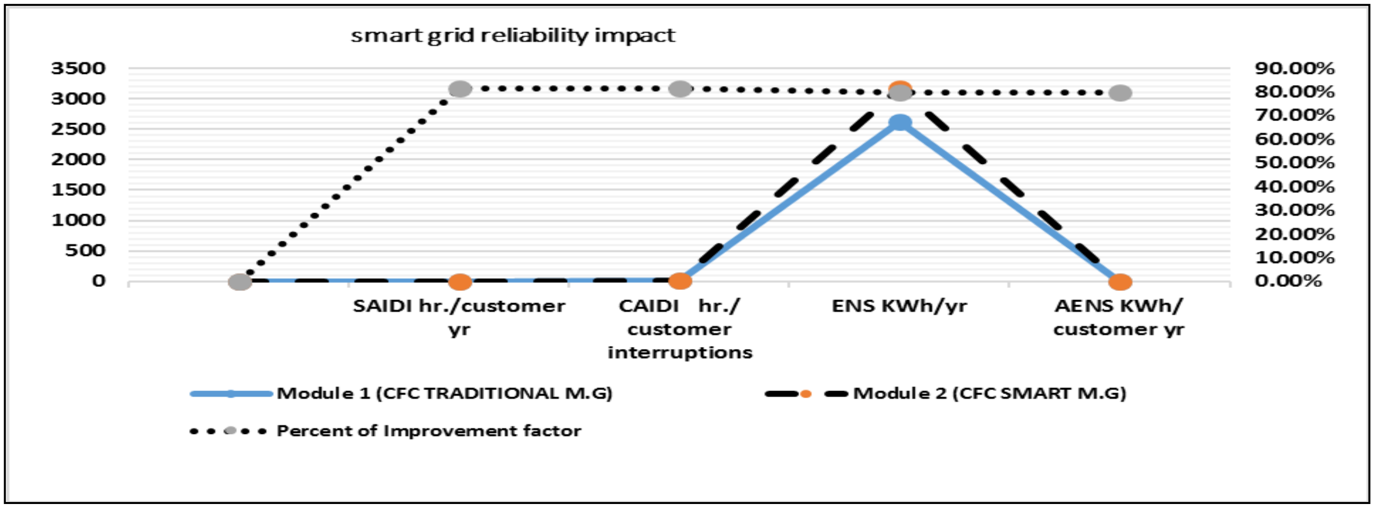

Fig 3 The improvement in reliability indices before and after smart tools

4- load shedding technique in smart grid.

Load shedding technique is aimed directly to maintain grid stability, and to prevent sudden blackout. The load-shedding system has three requirements.

Minimize process disruption

Work under all system topologies (bus configurations)

Operate in 60 m s or less

The primary scheme (Base-Case) uses a comprehensive power management system (PMS) that calculates predicted power deficits resulting from predetermined events (contingency based), using system inertia and governor response models for system generators. Knowing the spare in each generation unit versus the existing loads. This scheme will be executing in blind action in base case. In base case there will be spare generation will be used in case of island mode for this grid.

The secondary scheme (load shedding technique) is based on the following givings (pickup of under frequency relays, actual load value, using system inertia and governor response models for system generators, and satisfaction of the stability condition). The objective of the secondary scheme is to minimize the outage loads in case of the system frequency drops below operator defined thresholds. where there is no feed back of the load case. The feed back will be the system frequency pickup value, and according to that the load shedding will apply the priorities planes in cascading order till system frequency adjustment.

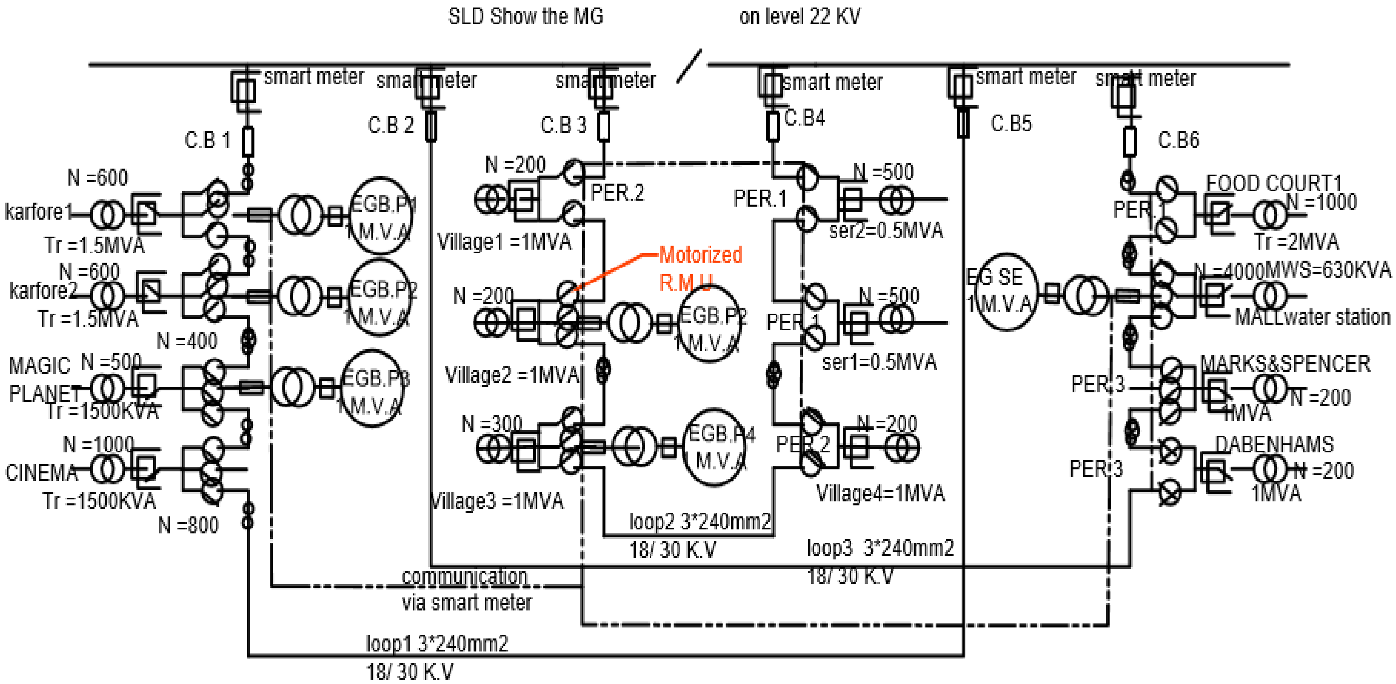

Fig.4 MV level grid in island mode showing (covered & uncovered loads)

4.1 Smart grid in island mode without load shedding techniques(base-case)

As shown in fig 4 the M.V network in case of a disturbance in the main grid. this mentioned network isolated from the rest of the project. During isolation from the main grid those units of generation synchronized one after the other over M.V level, this synchronization offers the load sharing where uncovered load also could be covered.

4.1.1 Grid Description

In this case, there will be isolation to the shown smart grid, which is group of loads connected to each other over the medium tension (22K.V). In case of normal feeding those loads, which estimated to be 6402 K.V.A after the diversity factor where there must be two action had been taken.

First: each mentioned load had a backup generator as mentioned in table 4 make start up and synchronized with the other backup generation over the medium tension grid as shown in Fig.4.

Second: backup generation will form Micro grid try to share each other to fed the loads without back up generation.

Third: in case of disturbance simulation as shown in this module (where there was shutdown suddenly happened in back up generation of karefor2) the load suddenly divided over the other backup generation. This will lead that most of the MCB (main circuit breakers) of the MDB (main low voltage distribution board) will trip over load. As each CB of the MDB is adjusted to tripe be triped within 1.2 of (nominal current) represent 0.8 of rated output current of backup generation.

Fourth: each back up generations returned back again to feed its own load only. Where there willnot be load sharring any more.

Table (4) loads value, spare generation power and grid stability condition in island mode.

TR. ROOM	Tr. Capacity (K.V.A)	LOADING FACTOR	LOAD AFTER DIVERSITY (K.V.A)	GEN.capacity (K.V.A)	Extra generation capacity K.V.A	uncovered loads K.V.A	stable operation condition
karfore1	1000	50%	500	1000	300	0	stable operation condition =extra generation - uncovered loads /extra
karfore2	1500	50%	750	1000	50	0	
Magic planet	1000	50%	500	1000	300	0	
cinema	1000	40%	400	1000	400	0	
villag1	1000	40%	400	0	0	400	
villag2	1000	40%	400	0	0	400	
village3	1000	40%	400	0	0	400	
village4	1000	40%	400	0	0	400	
food court	2000	50%	1000	1500	200	0	
Marks&							

4.1.2 Reliability indices computation assumption in base case (without load shedding)

The period of MTTS between isolation from the main grid and forming Micro grid till generators start up individually for each load and synchronizing with other generation is nearly 5 min. (0.083 hr.)

The MTTR either there is fault in the micro grid or there is temporary mechanical disturbance in the generator will take time to repair = 30 minute.

The repair time (Rs) could be calculated using this formula

Repair TIME (rs)

= (MTTS. *GEN%OF LOAD COVERAGE) + (MTTR. *%of un covered loads)

Assume that Gen. percentage of failure per year (f/yr=5%) and percentage of Gen. reliability95%

Outage time= [rs*95%] +[MTTR*5%]

N is the no. of customers.

The indices had been computed based on the scenario that there is disturbance in (Carefore 2 Generation). In this scenario the islanded grid stability condition will be affected. This disturbance leads to the outage of all the uncovered loads.

The blind action of the under voltage frequency pickup relay will disconnect all the uncovered loads to maintain system stability.

Table (5) show the reliability indices without using the load shedding device. The grid in island mode will disconnect all the uncovered loads in blind action. Based only on the under voltage frequency pickup relay all the uncovered loads will still disconnect till the grid mode of operation changed from island mode to connected mode.

Table 5(Reliability indices calculation without load shedding technique)

ISSN 2229-5518

Tr.ROOM	LOAD IN K.V.A COVERED	LOAD IN K.V.A UNCOVERED	repair time rs	OUTAGE TIMEUs	LOAD AFTER DIVERSITY(K.W)	Ni	Ni *λi	Us*Ni	Li *Ui
karfore1	500	0	41.5	39.45	625	2000	100.00	78900	24656.25
karfore2	0	750	375	356.275	937.5	2000	100.00	712550	334007.8
Magic planet	500	0	41.5	39.45	625	500	25.00	19725	24656.25
cinema	400	0	33.2	31.565	500	800	40.00	25252	15782.5
villag1	0	400	200	190.025	500	200	10.00	38005	95012.5
villag2	0	400	200	190.025	500	200	10.00	38005	95012.5
village3	0	400	200	190.025	500	200	10.00	38005	95012.5
village4	0	400	200	190.025	500	200	10.00	38005	95012.5
food court	1000	0	83	78.875	1250	2000	100.00	157750	98593.75
Marks&spenser	0	400	200	190.025	500	300	15.00	57007.5	95012.5
Dapenhams	500	0	41.5	39.45	625	200	10.00	7890	24656.25
service 1	250	0	20.75	19.7375	312.5	642	32.10	12671.48	6167.969
service 2	250	0	20.75	19.7375	312.5	642	32.10	12672.37	6167.969
water station	252	0	20.916	19.8952	315	3000	150.00	59685.6	6266.988
SUM	3652	2750			8002.5	12884	644.20	1296124	1016018
SAIDI		100.60							
CAIDI		2011.98							
ENS		1016018.24							
AENS		78.86							

4.2 Smart grid in island mode with load shedding techniques

4.2.1 Grid description

In this case the only addition is the load shedding device, which is connected with the CB of the MDB through the smart meter. This load shedding device which is programed according to the component address to apply the priority scheme. Using the smart meter as data bus to exchange the information and trip signals. When disturbance happened in karefore 2 generation this will lead to the underfrequency sensed by the load shedding device. Which apply the priority scheme in higher and shortest time response than the under voltage protection. Table4 illustrates the selected load-shedding scheme to protect overload condition and accordingly maintain system Stability. System inertia and the frequency band between pickup levels predicate the upper constraint on the selection of pickup time. Based upon these considerations, each generator operates separately, the pickup time of 0.1 seconds for all load-shedding steps is proposed through the simulation case studies.

Table 6 (Load shedding perriority scheme)

LOAD SHEDDING STEP	LOAD NAME	LOAD VALUE IN M.V.A * L.F	UNDER FREQUENCY HZ	TIME DELAY(MS)
1	MARKS&SPENSER	1000*50%	49.6	0.1
2	Village 1 Village2	1000*50% 1000*50%	49.4	0.15
3	Village3 Village4	1000*40% 1000*40%	49.2	0.18

Table (6) also based on the main fact that according to the value of under frequency the shedding priority will be first to the unit that is not shared with emergency Generator set. Also will be based up on the type of activity.

4.2.2Reliability indices computation assumption (with load shedding)

It will be the same assumption as mentioned before in (4.1.2), but with difference in the covered load.

In this case when disturbance happened in carefore2 the load shedding will apply the priority scheme. According to this scheme as mentioned in table 6 step 1& 2 loads will be disconnected. From the grid leave priority one connected. The grid maintains it's stability where reliability indices will be calculated based on those inputs as follow:

The repair time (Rs) could be calculated using this formula

Repair TIME (rs)

= (MTTS. *GEN%OF LOAD COVERAGE) + (MTTR. *%UNCOVERED LOADS(step1&2))

Table (7) show the reliability indices after using load shedding technique, how the indices improved after appling the priority one, and two in load shedding scheme. table 8 and fig.5 show the comparison between the smart grid with and without load shedding.

Table (7) reliability indices calculation with load shedding

Tr.ROOM	LOAD IN K.V.A COVERED	LOAD IN K.V.A UNCOVERED	repair time rs	OUTAGE TIMEUs	LOAD AFTER DIVERSITY(K.W)	Ni	Ni *λi	Us*Ni	Li *Ui
karfore1	500	0	41.5	39.45	625	2000	100.00	78900	24656.25
karfore2	750	0	62.25	59.1625	937.5	2000	100.00	118325	55464.84
Magic planet	500	0	41.5	39.45	625	500	25.00	19725	24656.25
cinema	400	0	33.2	31.565	500	800	40.00	25252	15782.5
villag1	0	400	200	190.025	500	200	10.00	38005	95012.5
villag2	0	400	200	190.025	500	200	10.00	38005	95012.5
village3	400	0	33.2	31.565	500	200	10.00	6313	15782.5
village4	400	0	33.2	31.565	500	200	10.00	6313	15782.5
food court	1000	0	83	78.875	1250	2000	100.00	157750	98593.75
Marks&spenser	0	400	200	190.025	500	300	15.00	57007.5	95012.5
Dapenhams	500	0	41.5	39.45	625	200	10.00	7890	24656.25
service 1	250	0	20.75	19.7375	312.5	642	32.10	12671.48	6167.969
service 2	250	0	20.75	19.7375	312.5	642	32.10	12672.37	6167.969
water station	252	0	20.916	19.8952	315	313	15.63	6217.25	6266.988
SUM	5202	1200				10197	509.83	585046.6	579015.3

SAIDI	57.38
CAIDI	1147.54
ENS	579015.27
AENS	56.79

Table 8.) reliability indices calculation for the smart grid with and without load shedding.

Reliability indices	smart grid without load shedding	smart Grid with load shedding	improvement %
SAIDI hr./ customer yr	121.87	57.38	52.92%
CAIDI hr./ customer interruptions	2437.41	1147.54	52.92%
ENS KWh/yr	1016018.24	579015.27	43.01%
AENS KWh/ customer yr	99.64	56.79	43.01%

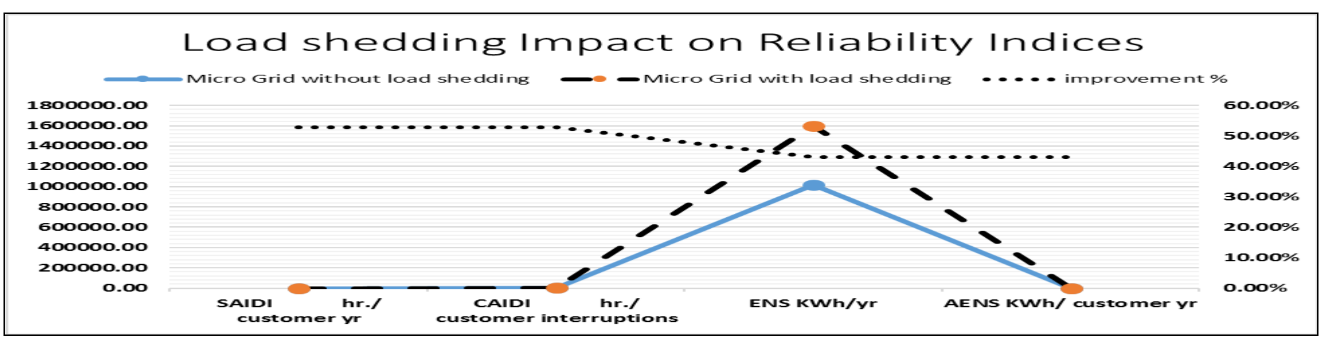

Fig. 5 comparison between the smart grid with and without load shedding

Conlusion:

Smart grid provides solutions to decrease both of the outage time, and outage loads.

The customer base indices is affected directly by the outage time (Ui), where the energy base indices is affected directly by load outage (Li). Smart grid achieves minimizing the outage time by (quick identification for fault location which estimated according to the manual operation record to be in average 30 minute where ever the fault location), this smart tools identify, and clears the faulty zone within 3 minute, and offer secure feeding source.

In the first issue the convertion from traditional to smart grid provide a good solution to decrease the repaire time from 2:30 hr to 2:03 hr. Decrease the repaire time by 27 minutes, the 27minute is the time needed for fault location identification and service restoration (FLISR). This is done by the first and second reclose of the automized switchgear. The quick mutual exchange between grid component using the smart meter as data bus lead to minimize the time of clearing the faulty zone.

The second issue in this paper show how the outage loads could be minimized using the load shedding technique. The second module is commercial and service grid, where in island mode the only covered loads is the loads provided with backup generation. In case of the presence of smart grid component in this commercial grid, the load shedding offers a good solution to use the spare of generation in each backup unit The presence of smart tools and the quick mutual data exchange between grid component (actual loads, frequency level, and generation governer response) provide suitable accurate data. These accurate data made the load shedding device achieve priorities planes for system stability. This technique decreases the outage loads, and maximize the usage of spare generation in case of islanded mode.

REFERENCES

1) David.Elzinga, Technology Roadmap Smart Grids, INTERNATIONAL ENERGY AGENCY, The International Energy Agency (IEA), an autonomous agency, This roadmap was prepared in April 2011, online at www.iea.org/about/copyright.asp Edited by Angelo Baggini, Handbook of Power Quality, John Wiley and Sons, Ltd.

2) Meysam Shamshiri, Chin Kim Gan, Chee Wei Tan," A Review of Recent Development in Smart Grid and Micro-Grid Laboratories", IEEE International Power Engineering and Optimization Conference, Melaka, Malaysia, June, 2012, pp. 367-372.

3) Michael J. Sullivan, B. Noland Suddeth, Terry Vardell, Ali Vojdani, Interruption Costs, Customer Satisfaction and Expectations for Service Reliability, IEEE Transactions on Power Systems, Vol. 11, No. 2, May 1996

4) P.Sailalitha, B.Kiranbabu," SMART GRID", International Journal of Engineering Trends and Technology (IJETT), Volume4, Issue4, April, 2013

5) Ron Allan, Roy Billinton, Probabilistic Assessment of Power systems, Proceeding of the IEEE, Vol. 88, No. 2, February 2000.

6) Roy Billinton, Ronald N. Allan, Reliability Evaluation of Power System, Second Edition

7) Sandia National Laboratory. Infrastrcuture: Energy assurance. Spiders (Smart power infrastructure demonstration for energy reliability and security). [Online]{Available}: http://energy.sandia.gov/?page_id=2781.

8) Tae-young Lee, Kwang-ho Ha, Hyun-jeaYoo, Jong-wan Seo and Myong-chul Shin, "Research for Data acquisition equipment with micro-Grid system", 5th International Conference on Electrical and Computer Engineering, IEEE, Bangladesh ,2008, pp. 712-715 .