Online Voltage-Frequency Measurement Based Micro-Grid Emergency Control,

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***Abstract*— in modern societies, there are a lot of problems such as economic and environmental constraints due to our tradeoff between past and new technology goals, in power generation, transmission, distribution. To solve these problems, much researches have been done to use green and cheap energy sources like solar and wind powers. Therefore modern power system grid get more changes from conventional power system grid. So, designers consider these changes in details based upon intensity of frequency deviation, frequency control process. For large frequency deviations, emergency control loop is needed. When a micro grid turns into islanded mode, to remain stability, total generation of DGs must guarantee the total load. Otherwise, the micro grid starts to collapse. To avoid this, a control strategy, called emergency control, is applied. In this paper, an algorithm is designed for load shedding in isolated micro grid, also dynamical details of a MG on its response are considered.**

Index Terms- Micro grid (MG), islanding, load shedding, Emergency control, distributed generation (DG), under frequency load shedding (UFLS), under voltage load shedding (UVLS).

I. NOMENCLATURE

MG	micro grid
UVLS	under voltage load shedding
UFLS	under frequency load shedding
DG	distributed generation
J	moment of inertia
H_i	inertia constant of the i^{th} DG
H_{eq}	equivalent inertia constant of MG
T_m	mechanical torque
T_e	electromagnetic torque
Pd	power deficit
f	nominal frequency of system in Hz
f'	frequency first derivative in Hz/s
S_i	apparent rated power of the i^{th} DG
ω	angular velocity

II. INTRODUCTION

Power system blackouts are a serious event for electric utilities. The recent system blackouts have occurred due to different forms of system instability such as voltage, frequency instability, and combination of voltage and frequency instabilities. To counteract each form of system instability, special algorithms are independently designed in the power systems, such as under frequency load shedding (UFLS) and under voltage load shedding (UVLS) schemes [2, 3]. One of the major weaknesses of these traditional algorithms is combination of different forms of instability is not considered in design, while a form of instability may not occur in a pure form. This is particularly true in the highly stressed systems and for cascading events [4]. At UFLS on conventional power system there is no fear for load shedding, because the whole system may collapse for a particular load and time delay between each step must be enough to avoid of overlap shedding [3]. In this paper, an algorithm is designed for load shedding according to the voltage–frequency measurement and then is applied to a micro grid (MG) case study. A new droop control strategy is presented in [1].

The basis of the MG entrance into the power systems is based on the increasing reliability of the conventional power systems, as well as improvement economic and environment issues. Using renewable energies in MG systems helps to reduce global warming and to speed up entering the power industry in the deregulated environments [1]. A hierarchical control strategy as shown in Fig. 1 [5]. It is shown in a MG that the frequency variation with normal changes in load tends to be much higher than main grid's frequency variation. Trying to correct this using low droop coefficient may lead to large variations the frequency [6]. It is shown that in a MG, the variation of frequency with normal load changes tends to be much higher than system grid frequency variation. Trying to correct this using low droop coefficient may lead to large variations in the frequency [6].

III. EMERGENCY CONTROL

Since an uncertainty in the nature of DGs and Constraints of Planning and electricity market have taken place, consequently the MG turns into islanded mode and its returning to its original shape is normal. Therefore, the emergency conditions remarkably increased in comparison to traditional power system, thus reliable design of an algorithm for maintaining stability in these conditions is required. Measuring appropriate parameters, recognizing emergency conditions and also have a properly performance. In connected mode, main grid acts as a reference bus for MG and imbalance power between generation and loads will compensated by the main grid. In the case of occurring severe disturbance in the system, the MG turns into islanded mode in order to avoid the probable collapse. At first the MG loads must be supplied, however, it is not possible to supply all the MG loads because of economic, planning and generation constraints (like uncertainty in wind power and so on).

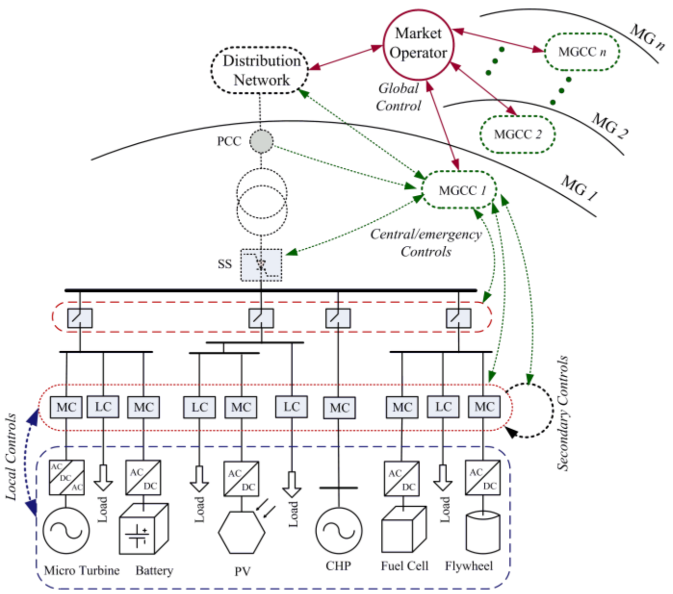


Fig. 1: A general scheme for MGs control levels. [5]

Thus the load shedding is required. Generally, load shedding procedure, includes the amount of loads that needs to be removed, the number of steps for load shedding, the amount of load that must be removed at each step, the location of load shedding and the time delay between each step. The proposed procedure, shown in Fig. 2, the online voltage and frequency measurements are used. To avoid much more load shedding, the location of loads regarding the importance of load and the cost are set. In conventional power systems, the overload condition is caused by faults, equipment failure, leaving of generating units and the lines outage. The Static and dynamic load shedding can be done in which each step is constant in the static load shedding and the dynamic characteristic of the system determine the steps in dynamic load shedding. Usually, the slow dynamic components can be ignored in emergency condition. Most recent researches are generally use only the voltage or frequency of MG, the power system outages as a serious problem can be occur due to various forms of voltage and frequency instability or either both. It is shown that, the active and reactive powers, impact the frequency in UFLS [15, 16, 17], also in MGs under overload conditions, the load shedding is essential, but differences between MGs and conventional power systems must be considered in load shedding. The determination of the inertia of such systems and consequently according to the swing equation, the amount of load that must be removed, is difficult. Emergency control dynamics is faster than other control loops, so they usually do not influence the emergency control, from [23]:

$$J\frac{d\omega}{dt} = Tm - Te \qquad (1)$$

$$H = \frac{J\omega^{\wedge}2}{2VAbase} \qquad (2)$$

From [24] for calculating power deficit we have:

$$Pd = \frac{2Heq}{fn} \times \acute{f}|t = t0 \qquad (3)$$

Where Heq is MG inertia equivalent which calculate from:

$$Heq = \frac{\sum_{i=1}^{n} Hi.Si}{\sum_{i=1}^{n} Si} \qquad (4)$$

The islanded mode occurs when a portion of the utility system becomes electrically isolated from the remaining part of the power system (because of disturbances or planning) and continues to be energized by DG units, An electrical island formed under these conditions should not last for a long time period, unless the aggregated active and reactive DG generation closely matches the load demand. Imbalance between generation and load that is usually causes cascading failures and blackouts in power system, likewise, the MG is. After disconnecting from main grid a stable islanded MG is possible. But keeping MG following tripping of a DG is impossible for controller. In this case, some loads based upon proposed procedure are shed. Our load shedding steps are according to a load shedding table that must be produced for the given case study. In general, proposed algorithm can be summarized in the following steps:

- Measuring voltage (V mes) and comparing with nominal voltage (V nom) to making decision.
- Measuring frequency (fr mes) and calculating rate of change of frequency (Δfr mes) and comparing both of them with their threshold (fr thr, Δfr thr) respectively to making decision.
- Calculating loads for load shedding is required if the last steps dismiss their limits.
- Seeing the effect of load shedding, the delay of K1 sec is required.

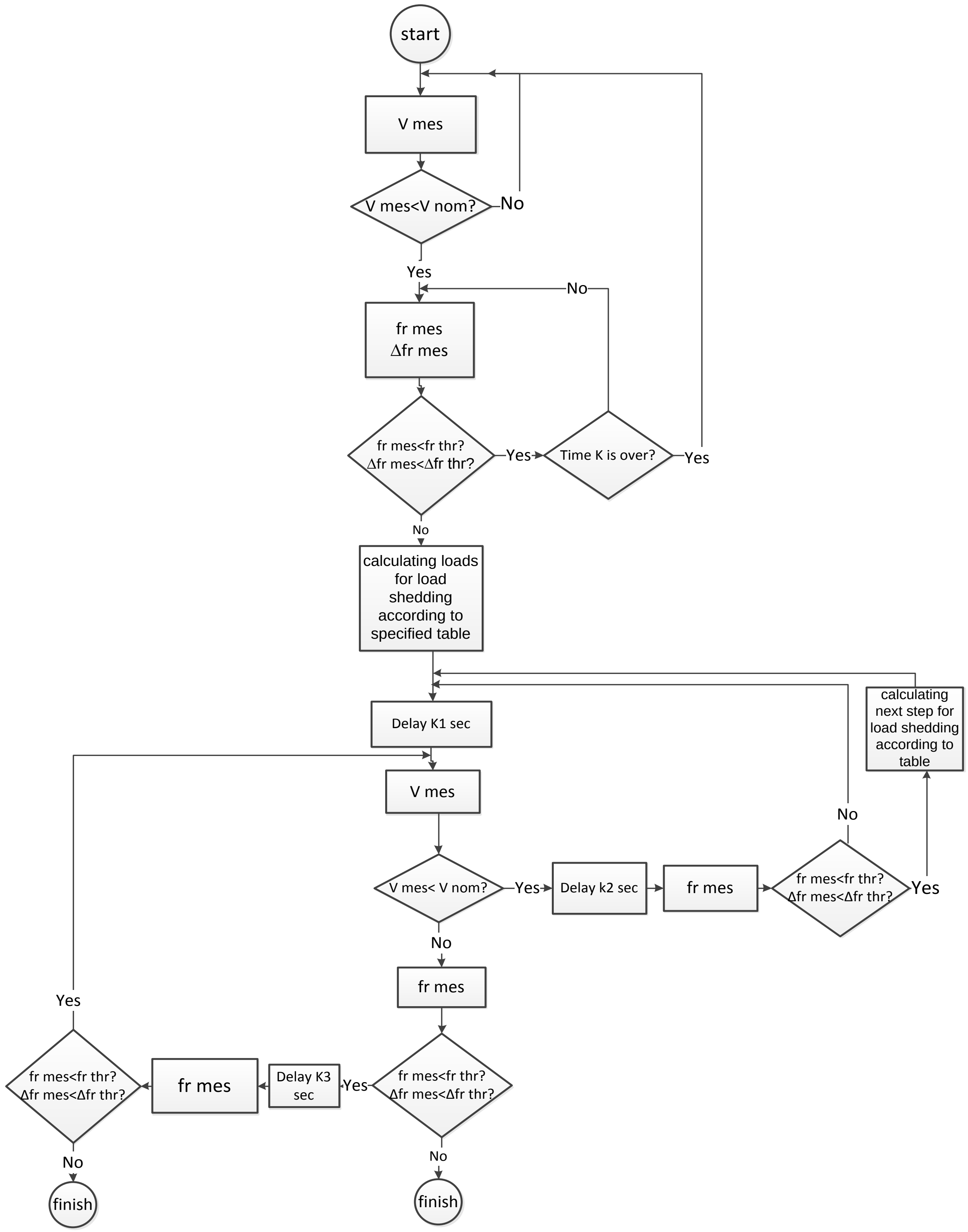


Fig. 2: Flow chart of designed load shedding algorithm

- Now measuring voltage (V mes), frequency (fr mes) and rate of change of frequency (Δfr mes) again required.

- These steps must repeat (as shown in Fig. 2) until measurement parameters return to the normal conditions.

- Delay K3 applied to filtering any possible disturbance in frequency of micro grid and to do that after K3 second delay measuring fr and Δfr if those dismiss their limits, algorithm come back to measuring voltage to ensure that we are in the emergency condition.

The thresholds and delays at each step in the proposed algorithm according to sensitivity of the MG and the dynamic characteristics of the MG determine respectively. Load shedding, both politically and economically affected, for example, the legal issues arising from participations and investments consumers can affect the load shedding [18]. Error reduces voltage and frequency at the point of connection of MG to the main grid, in MG with a high percentage of motor loads, voltage after the fault clearance not return to pre-disturbance and about the frequency, return to the normal state is too long or did not happen, The best place to do load shedding is where the voltage at the instant of fault clearance increase after that, if the voltage is acceptable, load shedding is not necessary, otherwise the voltage drop determines the amount of load shedding [19]. Load shedding, taking into account economic factors and removing minimum load to increase the transient stability micro-grid has been done [20]. The intensity of transition from connected to disconnect mode, dependent on factors such as MG conditions before islanding, the type of event, Type of MG sources [20]. Load shedding, taking into account economic factors and removing minimum load to increase the transient stability micro-grid has been done [21]. MG recovery after islanding, some loads that were disconnected by load shedding can be reconnected again. In order to avoid large frequency deviations during the load reconnection, it was assumed that it is possible to define a certain number of steps for load reconnection. This number of steps can be changed in accordance to the percentage of load shedding [22].

IV. CASE STUDY

When a MG turns to islanded mode by a circuit breaker, as DGs cannot supply the MG's load, the voltage and frequency of MG may collapse, to avoid this event usually load shedding is used but loads with lower priority must be curtailed first. Fig. 3 shows a MG which the central circuit breaker turns it into islanded mode in time t=2sec. and DGs output is given in Table I and loads in Table II, We can easily find out that DGs cannot supply all of loads and according to the designed load shedding algorithm some load blocks are distracted in times and in appropriate circumstances so MG will remain stable. Fig. 4, 5.

Table I. DGs active power output

DG1	DG2	DG3
2 MW	2MW	2MW

Fig. 5 display MG frequency and voltage magnitude in bus 5. Load shedding occurs in three steps at 3sec, 4sec, 5sec, and after that frequency and voltage magnitude return to the normal condition.

Table II. MG's loads

Load 1	Load 2	Load 3	Load 4	Load 5
3MW	2MW	1MW	0.2MW	3.2MW

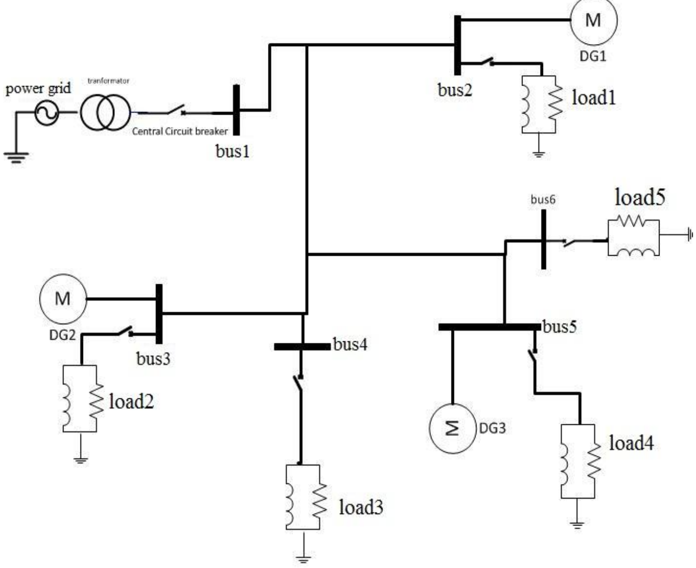


Fig. 3: The case study MG

As shown in simulation results, frequency and voltage are remained in an allowed range and MG is stable. If we do not use load shedding in a proper way, frequency and voltage may collapse, as shown in Fig. 6 and Fig. 7. The developed methodology represents a significant enhancement to the disciplines of corrective control and islanding for distributed power systems. Compared to the Early optimal load shedding approaches [11, 12], voltage-frequency based load shedding is more useful.

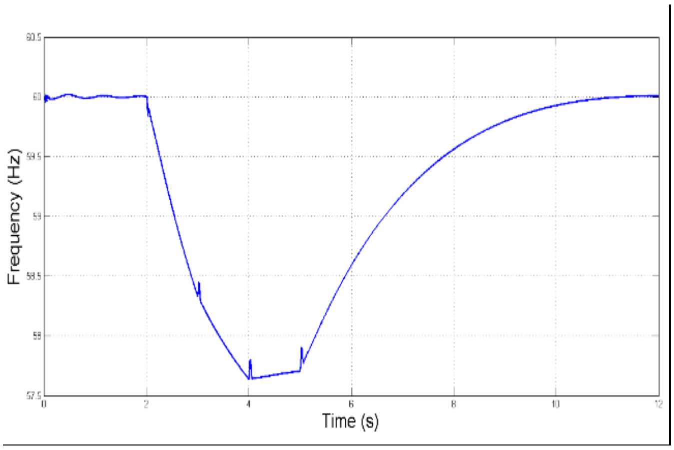
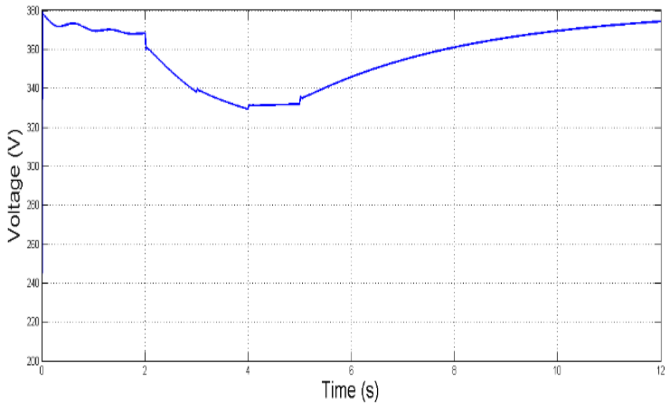


Fig. 4: MG frequency



MG voltage at bus 5

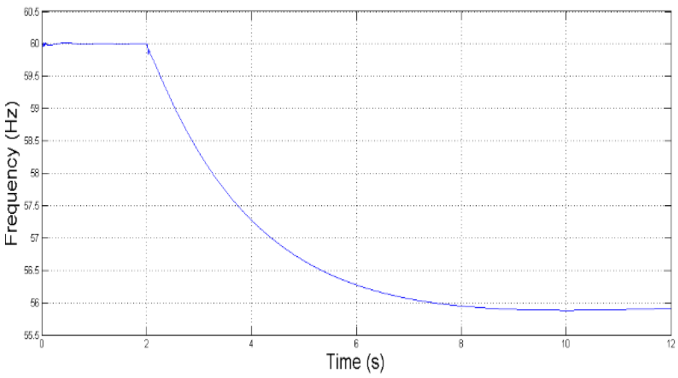


Fig. 6: MG frequency without load shedding

V. CONCLUSION

This paper proposed a new under voltage-frequency load shedding such that minimizes probability of occurring error in load shedding and thus instability in MG because an important issue raised in the ac MG is frequency and voltage magnitude regulation in the presence of disturbances, uncertainties, and load changes, both parameters of voltage and frequency affected by system structure, On the other hand MG as well as a power system can including instabilities: voltage instability, frequency instability, or a combination of both of them, so it is logical to consider both parameters in our load shedding algorithm.

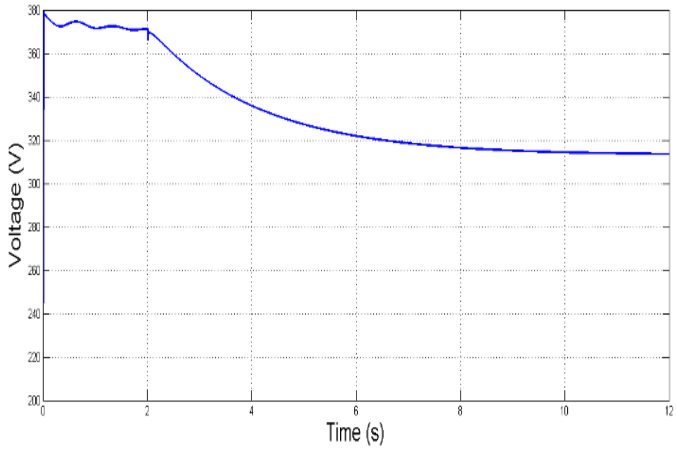


Fig. 7: MG voltage magnitude without load shedding

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