A Review on μ- PMU based Protection Scheme for μ-Grid and Distribution System

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ABSTRACT: Due to population rise ,pollution and mainly long transmission loss, the use of distribution energy resources (DER) like renewable energy sources, distribution generators(DG'S) and storage system on distribution system grown very rapidly. So, if we compare with traditional distribution system and new distribution system. It shows drastic change with lots of additional benefits. But, proper protection of these type of distribution system is very complex task .We required new and smart devices for handling effectively these complexity with proper solution and smooth data analysis. For these kind of smart operation ,we required adaptive protection scheme. Here in this paper, we review the use of micro PMU as adaptive protection scheme for micro-grid and distribution device.

Keywords: Distributed energy resources (DER), Micro-grid (MG'S), Micro phasor measurement unit (μ-PMU), Application of μ-PMU

1. INTRODUCTION

Due to high demand of energy, limited amount of fossil fuel and limited conventional energy sources, we required the proper utilization of renewable energy sources and distribution energy sources in current scenario[4]. For this purpose, we required new and smart distribution system where we can integrate many renewable energy sources and DER's in proper manner. This kind of integration is known as Micro-Grids(MG'S).

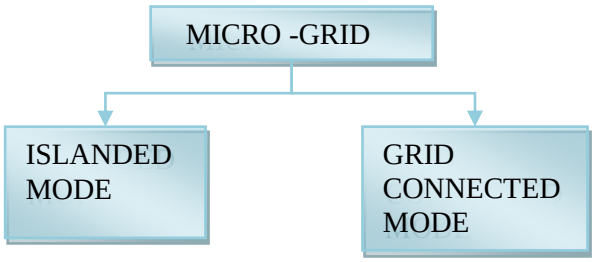

Fig. 1

In Islanded mode, all the load served through locally available distributed energy sources and storage systems.

In grid connected mode, MG's may get power from main grid or may feed excess power to the main grid.

After seeing the current scenario of need, we could get additional advantages from the use of μ-grid:

1. It improved the overall power supply reliability resiliency and power quality.
2. It provided environment friendly energy and reduced green house gasses.
3. It will be provided economic electricity and good service quality.

Due to the use of DEG's and new meshed topology introduced more complex impacts on the behavior of distribution system. So proper protection of μ-grid is a challenging task due to many protection issues[1]. There are following protection issues present in the μ-grid:

- In bidirectional power flow affected on amplitude and direction of current flow which makes problem in protection co-ordination of protective relays[1,4].
- In frequent changes in μ-grid configuration makes frequent change in SC fault current level which make over current relays grading complicated.
- In reduction in SC circuit fault current level, selectivity and sensitivity problem of over current relay to distinguish between main grid and μ-grid fault.
- μ-grid required smart, fast and reliable communication protection system.

So above issues could not solve by the conventional protection system because conventional distribution system is passive network but due to the use of

micro-grid and DER's is active network now.

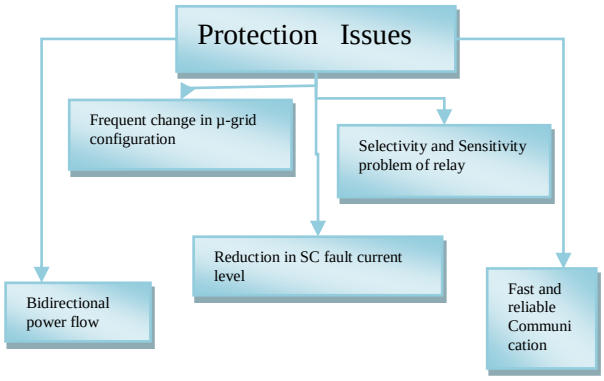

Fig. 2

Here, we divide our study on Adaptive protection scheme of micro-grid in five stages. Section 1 is introduction. Section 2 addresses the protection schemes for micro-grid and distribution system. Section 3 addresses different between PMU and μ-PMU. Section 4 addresses the principle of adaptive protection schemes. Section 5 concludes the paper.

2. PROTECTION SCHEMES FOR MICRO-GRID

We have two types of protection methods for micro-grid and distribution system:

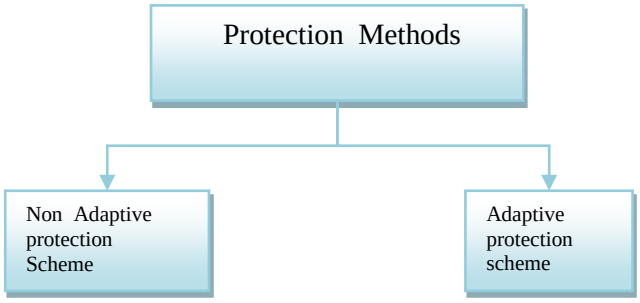

Fig. 3

Non-adaptive protection scheme is also known as conventional protection system for distribution system. it does not provide proper protection to the μ-grid [13]. Due to above mentioned issues it does not provide proper co-ordination when one or more lines in a system go out of service for any kind of problem. The operating time of system is also high which is not desirable for distribution and micro- grid protection[1].

Adaptive protection is new and smart ways of protection of distribution system. Adaptive protection scheme provide optimum setting for ach operating and connection. It required less operating time of relays. In past we used SCADA and IES for real time monitoring but they suffer from many serious problem like significant time delay and considerable measurement error respectively[1].

3. DIFFERENCE BETWEEN PMU AND μ-PMU

The adaptive protection scheme with synchrophasor technology is applicable in both conventional PMU and μ-PMU. But here we are studied about protection scheme for micro-grid and distribution system. So we preferred micro PMU as compare to PMU[2,5].

There are following reason for selecting micro PMU instead PMU:

a. Features of μ-PMU and PMU:

S.no.	μ-PMU(PQube)	PMU(Arbiter)
1.	GPS synchronization	GPS synchronization
2.	Recoding rate:120/sec at 60Hz	Recording rate: up to 60/sec for 60 Hz
3.	Voltage phasor, Current phasor, Frequency, Active and Reactive power, Power factor	Voltage phasor, Current phasor, frequency, Sequence voltage Active and Reactive Power

b. Here we compare the performance of PMU and μ-PMU:

- Normal condition: In normal condition ,there output phasors are almost same but the reporting rate of micro PMU is 120/sec and the reporting rate of PMU is 60/sec[2].
- Full voltage drop: Here the magnitude and angle changes are almost same but there is slightly delay response from micro PMU to PMU. This delay around 4 to 6 cycles. But PMU jumps in phasor calculation[2].
- Partial voltage drop and Phase angle change: Here, Micro PMU is more accurate in small angle calculation than PMU. The frequency calculation of micro PMU seems more stable than PMU[2].

So above comparison shows a clear view that μ-PMU is very useful tool for the micro-grid and distribution system as compare to conventional PMU.

3. PRINCIPLE OF ADAPTIVE PROTECTION SCHEME:

Adaptive protection schemes working on synchronized phasor measurement technique. Synchronized are time-synchronized numbers that represent both the magnitude and phase angle of the sine waves found in electricity and are time synchronized for accuracy.

3.1 SYNCHROPHASOR TECHNOLOGY: Synchrophasor give an optimal solution to the problem of time-incoherently and data. In synchrophasor monitoring and controlling of power system, time reference is kept same for all parameters and it is taken as t_0 [9].

In protection system, phasors of frequency, current, voltage and power are considered for processing and analyzing safe working condition[12].

For wide area monitoring system(WAMS) traditionally SCADA or other methods were being used which unable to capture real time dynamics of the system[3]. But the advantage of μ-PMU have synchrophasor technology, makes it more reliable[10].

For controlling purpose, synchrophasor vector processor(SVPs) were used which were connected to local measurement an control units making it as a wide area power control system[11].

3.2 EXISTING PROTECTION SCHEMES:

In electrical system, protection schemes means to control and limit the damage of equipment by separation of faulty section as quickly as possible. Here in this paper ,we reviewed mainly three algorithms on protection schemes of μ-grid :

i. Based on travelling wave theory

ii. Based on topology processor module

iii. Based on graph theoretic way

- Algorithms based on travelling wave theory is using Clarke transformation to decouple the phase components in voltage and current signal to obtain the propagation time constant (Γ), fault coefficient index(D_{ij})and abnormality constant(∂_{ij})[4]. This protection scheme algorithms is used fig.(4)[4] .

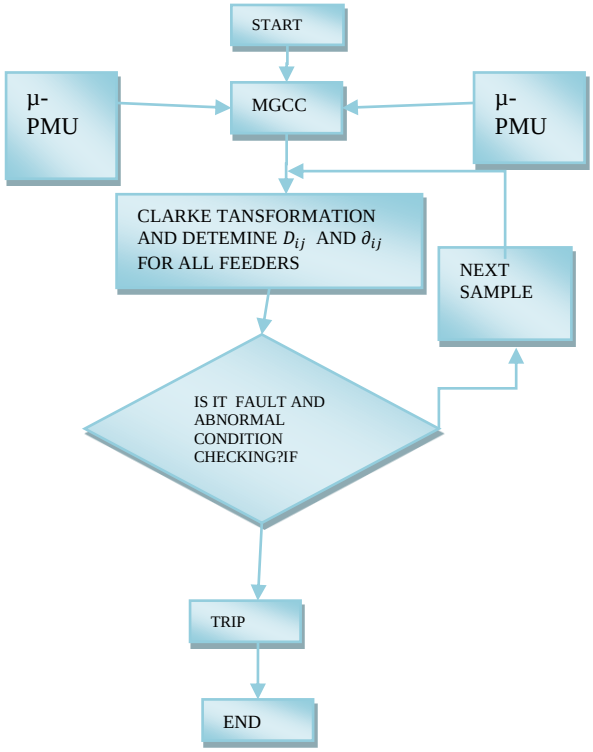

Fig. 4

Event look-up table for fig(4):

D_{ij}	∂_{ij}	Event
0	0	Normal operation
0	1	Abnormal case
1	0	SC fault case
1	1	Fault and abnormal case

This scheme has the advantage of synchronized data and time -tagged measurement. This scheme reduced the problems of measurement overlapping in conventional schemes.

- Topology processor module, we used μ-PMU's real time measurements feature to get correct topology of μ-grid[8]. In this protection we can calculate fault current and co-ordination status of all possible primary back up relay pairs. This protection scheme algorithms used.

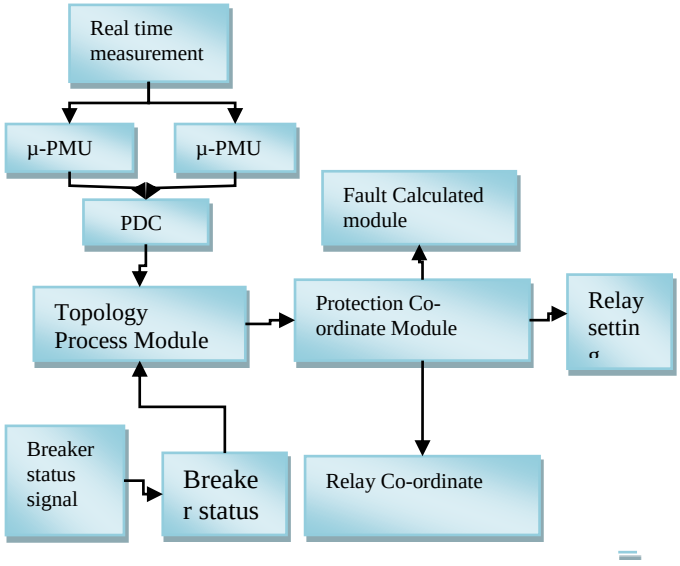

Fig. 5

Here, From existing setting to updated setting required some time:

i. Topology processor (2.0 sec)
ii. Short circuit calculation (0.1 sec)
iii. Checking miscoordination (0.05 sec)
iv. Setting calculation(1.5 sec)
v. Communication link delay(0.1sec)

So, we can see that it required only maximum 3.75sec[8].

- In graph theoretic way, we are graph model concept to solved optimal PMU placement problem[7].

In smart grid, completely observable distribution system is must. With the help of μ-PMU, we could get the information about mainly four things:

i. Voltage phasor
ii. Current phasor
iii. Frequency
iv. Rate of change of frequency

Here we used graph method to solve the optimal placement of μ-PMU problem.

System observability and μ-PMU placement formulation:-

- Observability of a System:

For observable system, All the bus voltage phasors obtain from measurement[7] .

Working of μ-PMU in Graph theoretic way:

μ-PMU directly measured the voltage phasor and current phasor of the μ-PMU installed buses and incident lines respectively. Voltage phasor of adjacent buses are calculated by using the voltage and current phasor measured by the micro-PMU.

For a completely observable system,

$$\sum_{i}^{n} = F_i X_i$$

Subject to $f(z) \geq c$

Where f(z)=binary vector for μ-pmu installation which gives Z_k

$$Z_k = \begin{cases} 1, & if\ ith\ bus\ is\ selected\ for \\ & \mu - PMU\ installation \\ 0, & Otherwise \end{cases}$$

Optimal PMU placement technique has been formulated here in two stage :-

In stage 1, we find the unobservable vertices and group them. Here maximum number of clusters is 3.

In stage 2, Install a μ-PMU, which make system completely observable economically.

Algorithm shows in fig(6)[7]. This method is very simple and state forward.

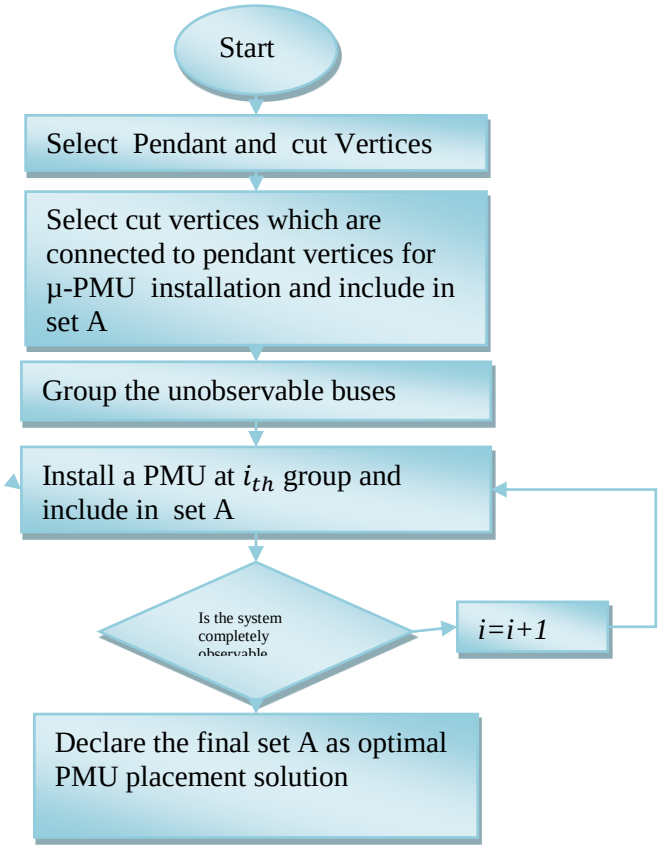

Fig. 6[7]

μ-PMU is used for complete observation of the system so it's placement is very important. The use of graph theory gives very optimal result for the placement of μ-PMU economically.

All the above adaptive protection schemes increase the efficiency , reduced the faulty condition and improve the observability of the system.

4. CONCLUSIONS

This paper reviewed many key papers in the field of μ-PMU based protection scheme of micro grid and distribution system.

Wide area measurement system application with of phasor measurement unit is an important method in μ-grid and distribution system.

Synchrophasor data from μ-PMU is responsible for raising situational awareness, generator tripping by observing frequency decrease, df/dt ratio increment, change of angular separation and voltage magnitude decrease. Also this data is used for offline for keeping record of fault levels and danger management for future reference.

But it required some advancement in μ-PMU which uses only GPS as time synchronization tool. Here we can use dual or multi- time synchronization to improve accuracy and stability in power system.

Synchrophasor technology also have some major disadvantages like signal security, latency and synchrophasor signal quality which are further dealt by keeping parameters range according to the standards.

Before utilizing this technique .it is required to focus on some important aspect of the distribution system :

1. cost benefit analysis is must before installation of μ-PMU.
2. It required extensive communication infrastructure.
3. Adaptive relays have short life.

Due to above things, we can said that μ-PMU as a protection scheme required more research and up-gradation which improve the quality of result and protection of μ-grid's.

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