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Investigate Single Exit Event and Installation Constraint of PMU for Full Observability the Transmission Network Khuzestan Province

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ABSTRACT

In this paper, because the elecommunication constraints on in some buses network, will be provided the method for optimal Placement of phasor measurement units despite the installed limitations on some buses. Also to keep observability in the event of single loss with considering these limitations, the optimal placement problem is studied. Problem-solving algorithms is binary integer linear programming in MATLAB software environment and case studied is 230 and 400 kV transmission network in Khuzestan province. The results is indicate the optimal placement of phasor measurement units with full observability network with installed limitations on some buses and single loss event.

Keywords: Phasor Measurement Units, optimal placement, observability, Installation restrictions, single loss unit

I. INTRODUCTION

Careful observed the modes of network performance are done with available state estimators in control center that are access to the various posts measurement. In the traditional approach, these measurements had been nonsynchronous, and were obtained with the presence conventional measurement units in substations. This measurement was consists of active and reactive power in this line and power injection to buses. Nowadays with the advent of phasor measurement units (PMUs), there is possible to synchronous measurement [19]. These units through the resive of time pulse signal that through the satellite global positioning system (GPS), to their measure signals account the time labels until in this way able to be achieved angle relative or phasor of measured the voltage and current[12,13]. PMU is that able to conversion of nonlinear state estimation equations of normality the network to linear equations, and in turn be improve the speed control systems, conservation and management, that uses the results of state estimation [14,15,16].

Power Systems in addition to economic considerations, should be cohesive format to be designed that against the all possible stress to continue his work. One of these stress, is single exit phasor measurement units in power system. So for continuous state estimation in power system, is necessary be done placement this units in such a way that in case of occurrence this event, continue to be provided the complete observability of system [5,10]. In [5,6,12,13,18] has been to observability issue in case of loss of PMU, in the problem of optimal placement of PMUs. Since On in some buses due to communication constraints does not exist installed of PMU and should be these buses indirectly observable [9].In this paper, have been investigated the impact of these limits Under normal placement conditions, And coincides with the probability of exit single PMU.

So in this respect in the next section is investigated to explanation of observability the power system by PMU and the introduction of the BOI and SORI. In Section 3, is investigated the optimal placement problem and formulate it with the aim of full observability network. In Section 4, the optimal location in the event of loss of a PMU. And in section 5 have been investigated optimal placement of PMU with the limitations installation in some buses. Simulation algorithm in this paper Due to respond more quickly and efficiently is Binary integer linear programming (ILP).

Observability of power system by PMU:

The observability of a power system is defined as the calculation of system variables in order to estimate system state [2] PMU installed on a certain bus is able to measure the voltage phasor of that bus. As a result voltage size and phase angle connected buses to bus equipped the PMU also can are calculated with Kirchhoff relations. So the buses that in their have been installed PMU, are directly observed, and buses that are connected to the bus with PMU, they are indirectly observed [2,11,19].

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The number of PMU that have the potential observability of a bus say the bus observability index (BOI), and the sum of bus observability for all the busses of a system, is say the (SORI) [7]. In other words, if observable indicators to bus i is (β_i) thus SORI obtained as the equation (1) [9]:

$$\mathrm{SORI} = \sum_{i=1}^{n} \beta_i \tag{1}$$

Placement the Phasor Measurement units

the problem of optimal PMU placement is one where the objective is to minimize the number of PMUs utilized while preserving the system observability.

For this purpose, it is sufficient to know the system topology (interconnection method buses and lines) and the type of system buses. The system bus connections are displayed using a system connectivity matrix [2]. This matrix shows the interconnection of buses by transmission lines. Here, denoting A as the connectivity matrix and N as the number of system buses, A forms a n × n matrix with the entries defined as equation (1) [3,4,8,17]:

$$A_{n\times n}(i,j) = \begin{cases} 1 & i = j \\ 1 & \text{if buses i and j are connected} \\ 1 & \text{otherwise} \end{cases} \tag{2}$$

The discrete nature of the optimal PMU placement problem requires the vector X to be defined as equation (3) such that its elements show installation status of a PMU on each bus[1,3,4,8,17]:

$$[x]_i = x_i = \begin{cases} 1 \text{ if PMU is installeat bus i} \\ 0 \text{ otherwise} \end{cases} \tag{3}$$

The formulation of the optimal placement of PMU in a system with n buses is presented as equation (4) and (5) [1,3,4,8,17]:

$$\min \sum_{i=0}^{n} x_i \tag{4}$$

$$s.t \quad f(x) = Ax \geq b \tag{5}$$

Since the purpose of optimal placement of phasor measurement units, find the minimum number of buses to install the unit on them, total network is observability, b matrix is defined as equation (6) [3,4,8,17]:

$$b_{n\times 1} = [1\ 1\ 1 \ldots 1 1]^T \tag{6}$$

Optimal Placement of PMU Constraints in the case of a Single PMU Loss

Like other applied to equipment in power system, also there is probability exit the PMU. To ensure the full observability of power system, if a single PMU loss, should be constraints are defined this problem of such that could be calculated the voltage phasor each buses of system at least methods. In other words, each system bus must be at least observable twice.

So $b_{n\times 1}$matrix in (5) for maintain observability of system in this case of the placement PMU, changes to (7) [5,6,12,13,18].

$$b_{n\times 1} = [2\ 2\ 2 \ldots 2\ 2]^T \tag{7}$$

Optimal Placement of PMU considering the Limitations Installing on Some Buses

Due to lack of communication and telecommunication facilities in some of the buses systems, there is no possibility to install of PMU in such buses, and direct observability of these buses is not possible[4]. So the formulated problem must be in a way to change these buses to be indirectly observable and monitored. For this purpose after determining these buses, their placement is defined as equation (8):

$$\begin{aligned} &\min \sum_{i=1}^{n} x_i \\ &\text{subject to: } A_{n\times n} \times X_{n\times 1} \geq b_{n\times 1} \\ &A'_{n\times n} \times X_{n\times 1} = b'_{n\times 1} \\ &X_{n\times 1} = [x_1 x_2 \ldots x_n]^T \end{aligned} \tag{8}$$

$x_i \in \{0,1\}$

In the above equation, the $A_{n\times n}$matrix, $b_{n\times 1}$ and $X_{n\times 1}$ vectors of the same basic model, shown in equations (2), (3) and (5) are defined. Equality $A'_{n\times n}X_{n\times 1} = b'_{n\times 1}$is a related constraint to the buses that installation of PMU is limited. Also $A'_{n\times n}$ matrix and $b'_{n\times 1}$ vector are expressed as well as equation (9):

$$A'_{n\times n}(i,j) = \begin{cases} 1 & if\ i = j\ and\ PMU\ can\ not\ be\ installed\ bus\ i \\ 0 & otherwise \end{cases}$$

$$b'_{n\times 1} = 0 \qquad (9)$$

Simulation results placement PMU

In this paper, to evaluate the ability of the proposed formulation, is obtained optimal number and location of Phasor Measurement Units in 230 and 400 kV Khuzestan province network for provide four objectives following :

Stage 1) full observability in normally mode

Step 2) observability with considering the limitations installing on some buses

Step 3) observability in event single loss of a PMU

Step 4) observability with considering the limitations installing on some buses and single loss of PMU

Figures (1) and (2) shows network diagram 230 and 400 KV Khuzestan province in Iran. In table (1) is presented post names for better clarity network and easier analysis it.

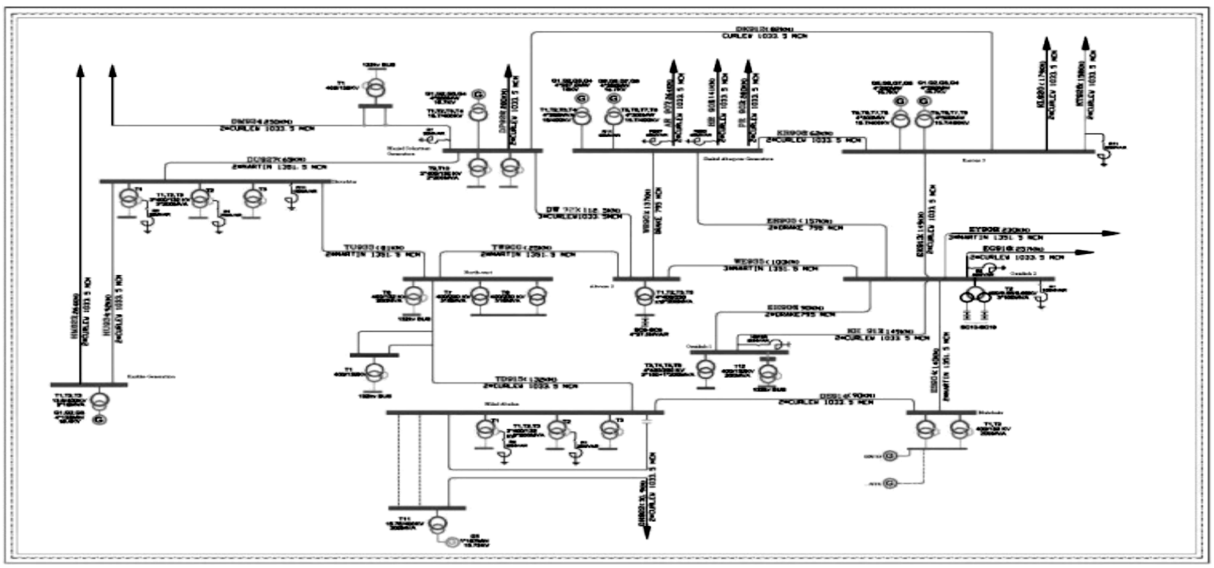

Figure1. 230 KV network in khouzestan province

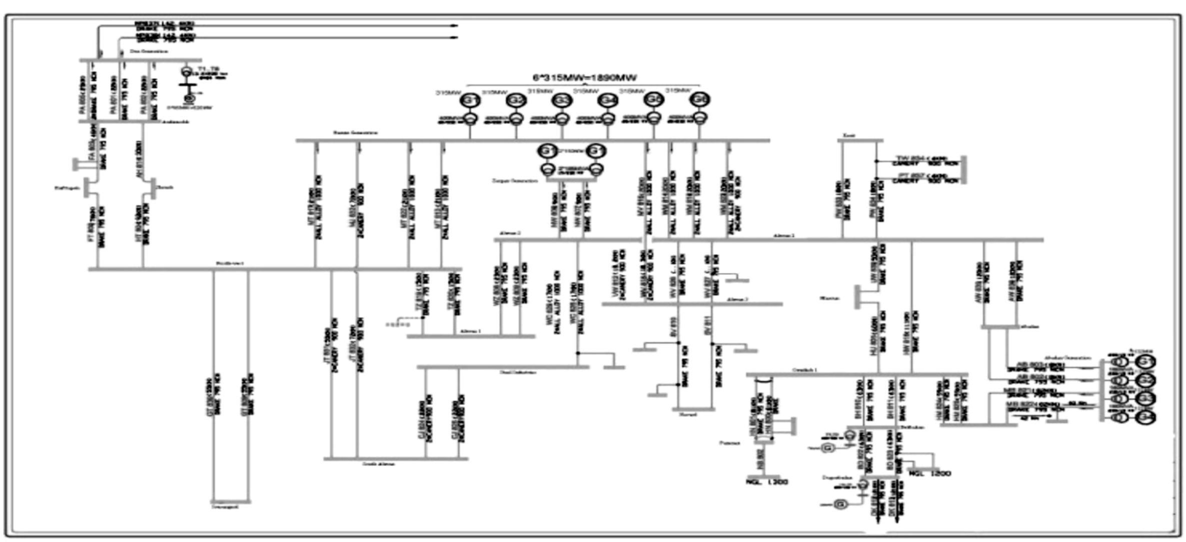

Figure2. 400KV network in Khouzestan province

TABLE1. The post names of Khouzestan province

230 KV Khouzestan province		400kv khouzestan province	
Post number	***Post name***	***Post number***	***Post name***
1	Ramin Generation	1	Shahid Abaspour Generation
2	Abadan Generation	2	Karoun 3
3	Dez Generation	3	Masjed Soleyman Generation
4	Zergan Generation	4	Karkhe Generation
5	Ahwaz 2	5	Ahwaze2
6	North-west	6	Milad Abadan
7	South Ahwaz	7	Omidieh 1
8	Steel Industries	8	Omidieh 2
9	Abadan	9	Mahshahr
10	Omidieh 1	10	Shoushtar
11	Behbahan	11	North west
12	Dogonbaadan	-	-
13	Ahwaz 1	-	-
14	Andimeshk	-	-
15	Hafttapeh	-	-
16	Shoush	-	-
17	Ahwaz 3	-	-
18	Navard	-	-
19	Pezenan	-	-
20	Maroun	-	-
21	Kerit	-	-
22	Sousangerd	-	-

Stage 1) full observability of normally mode

At this stage, using equation (2) - (6) is shown the number and location PMU in normal state in table (2). Also in table (3) with BOI and SORI is investigated the observability in placement to manner table (2).The results in table 2 and 3 show with equipped 27 and 36 percent of the buses 230- and 400-network khouzestan province with phasor measurement units can be observable.

Table2. Number and Positioning the PMU for 230- and 400-network khouzestan province in normally mode

Test system	**No. of PMUs**	**Location PMUs**
230KV khouzestan province	6	5,8,10,11,14,17
400KV khouzestan province	4	2,3,9,10

Table3. BOI and SORI for placement of PMU such as the table 2

Test system	**BOI**	**SORI**
230KV khouzestan province	3,1,1,1,3,1,1,1,1,3,2, 1,2,1,2,2,2,1,1,2,1,1	34
400KV khouzestan province	1,2,3,1,1,1,1,1,1,2,1	15

Stage 2) observability with considering installation restrictions on some buses

At this stage is assumed that the buses number 2,6 in 230 kV network and buses number 2,5 in 400 kV network of khouzestan province due to lack of suitable telecommunications facilities on them are the installation limitations of PMU. Hence, the optimal number and location of PMUs and observability of the buses, considering this restrictions in Table (4) are shown. Also in table (5) with BOI and SORI is investigated the observability in placement to manner table (4).The results show of full observability network is retained by changing the location of the PMU and not to install it on buses is restricted.

Table 4. Number and location of PMU with considering installation limitations in some buses

Test system	No. of PMUs	Buses that haven't installed PMU	Location PMUs
230KV khouzestan province	2,6	6	5,8,10,11,14,17
400KV khouzestan province	2,5	4	1,6,7,10

Table 5. BOI and SORI in optimal Placement of PMU with considering installation limitations in some buses

Test system	BOI	SORI
230KV khouzestan province	3,1,1,1,3,1,1,1,1,3,2, 1,2,1,2,2,2,1,1,2,1,1	34
400KV khouzestan province	1,2,1,1,1,1,1,2,1,1,2	14

Step 3) observability in event single loss of a PMU

In this step, survey the maintaining observability with event of single loss of PMU in 230 and 400 kV Khuzestan network. Table (6) shown optimal placement of PMU with considering single loss of PMU, and table (7) shown BOI and SORI for locating table (6) to study the observability of the system.

Results of this tables shows for full observability of 230 kV Khuzestan province network in this step, need to equip 68% of buses network, and the 400 kV Khuzestan network need to equip 63% of the buses with PMU. In other words, will result increasing the observability of each bus from least once, to least twice, and thus increase SORI.

Table 6. Number and location of PMU with considering single loss of PMU

Test system	No. of PMUs	Location PMUs
230KV khouzestan province	15	3,4,5,7,8,9,10,11,12, 14,17,18,19,21,22
400KV khouzestan province	7	2,4,7,8,9,10,11

Table 7. BOI and SORI in optimal Placement of PMU with considering single loss of PMU

Test system	BOI	SORI
230KV khouzestan province	4,2,2,2,6,2,2,3,2,4,3, 2,2,2,2,2,3,2,2,2,2,2	55
400KV khouzestan province	2,2,2,2,2,2,3,3,2,3,2	25

Step 4) observability with considering the limitations installing on some buses and single loss of PMU

At this step of optimal placement, is investigated the probability of single loss PMU limitations installing on some buses, in 230 and 400 kV Khuzestan province network. Table (8) is specifies buses with limitations installing on them, and the optimal number and location of the PMU in this step. Also Table (9), is show the BOI and SORI to placement of PMU such as the table (8). The results is shown increase number and the BOI and SORI in this step from placement of PMU than investigate of the possibilities of single loss of PMU alone in the 400 kV Khuzestan province network. So in general, there are the possible increased of number of PMU at this stage than stage 3.

Table 8. number and location of PMU with considering installation limitations in some buses and single loss of PMU

Test system	Buses that haven't installed PMU	No. of PMUs	Location PMUs
230KV khouzestan province	2,6	15	3,4,5,7,8,9,10,11,12, 14,17,18,19,21,22
230KV khouzestan province	2,5	8	1,3,4,7,8,9,10,11

Table 9. BOI and SORI in optimal Placemnt of PMU with considering installation limitations in some buses and single loss of PMU

Test system	BOI	SORI
230KV khouzestan province	4,2,2,2,6,2,2,3,2,4,3, 2,2,2,2,2,3,2,2,2,2,2	55
400KV khouzestan province	2,3,2,2,4,2,2,4,2,4,2	29

Conclusion

In this paper for optimal placement of phasor measurement units to full observability of network, have been investigated the installed limited problem on some buses of network due to communication restrictions on this buses with using Algorithm integer linear programming Algorithm (ILP) in 230 and 400 kV network of Khuzestan province. Also according to the relationships presented in this paper, has been determined the new optimal location for installation of PMU. Also Investigate the keep observability of network in the event of single loss PMU , and results from this shown an increase of 36% for the 230 kV network And 32% for the 400 kV network of Khuzestan, with at least twice observability of buses to increase the reliability. Finally, the number and location of the PMUs with considering the installation limitations these measurement on some buses Simultaneously the Probability of occurrence of a single loss of PMU, shown the increase number and observability of buses in 400 kV network of Khuzestan province.

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