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Protection of Interconnected Transmission Network using Phasor Measurement Unit Scheme

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Abstract – *The demand of load is increasing everyday but the transmission resources are very limited because of various challenges and constraints faced during power system monitoring. This insufficiency of transmission resources had lead to reduced operational margins for power system operators. Further due to this heavy loading the stability limit has reached it maximum value. Therefore this issue of deregulation has lead for the development of wide monitoring, protection and control rather than traditional scheme. This paper proposes an adaptive protection scheme which is based on phasor measurement unit (PMU) for the protection of power system network. Here positive sequence voltage and currents of transmission lines are used to identify the location of fault. The fault location is located at maximum speed and accuracy with the help of PMU's placed over a wide area transmission network. This paper shows results of IEEE 5 bus system which is been simulated on MATLAB/SIMULINK platform for various fault conditions.*

Key Words: Smart Grid, smart management, smart networking, distributed generation, smart protection systems, PMU;

1. INTRODUCTION

One of the important aspect of smart grid system is two way communication between consumers and power system operators. This enables the power system to act smartly and provide proper isolation from faults. Differential verification of angles and magnitude of voltage and current phasors are the basis of differential protection overspeeding (DPO). Also is also depends on the rate of change of electric measurement. [1] Shows the function of DPO protection, according to which the comparison of phasors angles may be used in order to determine certain measurable quantities so that they should lead to the detection of a perturbation occurrence. With the great expansion of power system network, the quality of uninterrupted power is being demanded for which wide area measurement system (WAMS) is being used. Phasor measurement unit (PMU) is the revolutionary invention and have the potential to monitor and control the power system parameters [1].

Synchronized measurement of voltage and current phasors is possible with the help of PMU's [2]. Synchronized measurements of voltage and current phasors are achieved with the help of PMU; this is done with the help of global positioning system (GPS). The phase position of voltages and currents in different areas of wide area power system is possible with the help of PMU's. Therefore it has become easier to determine the stability and dynamic performance of huge power system network. Apart from this PMU's also measures the frequency and the rate of change of frequency too. Positive sequence voltage phasors are usually used to measure the characteristics of power system on real time basis since it determines the system frequency and the change in frequency [3] [4]. The computerized real time analysis of phasor parameters of voltages and currents has been introduced [5].

The use of various applications related to accuracy of synchronization has been implemented for the measurement of angle and magnitude of phasors [6]. Various advantages of launching PMU, WAMS technology for controlling, securing and supervising has been discussed [7][8]. Discrete Fourier transform based method of PMU has been proposed with the help of simulation software's like MATLAB and LABVIEW for the estimation of phasors [9]. Micro PMU's and their applications have been discussed [10] for the applications of synchrophasor technology in distribution system. Approximation algorithm for supervision of distribution network has been presented for the functioning of PMU [11]. IEEE 34 bus system has been analysed for dynamic and modelling of distribution network where different types and levels have been presented [12]. Optimal solution has been determined by state approximation of all buses in a three-phase network using Integer Programming Optimization (IPO) and Greedy Algorithm [13].

This paper presents the results of wide area network monitoring protection and control using PMU based model which has been tested on 5 bus system using MATLAB simulink. The results of the performance of PMU based algorithm has been discussed in result section.

2. PHASOR MEASUREMENT UNIT

The technology of phasor measurement unit comprises of parameters like phase angle, magnitude and both in synchronized manner. All the parameters are acquired in real time basis and is transferred to power system operation system for proper isolation using GPS technology [14]. The accuracy of PMUs totally depends on this real time information which is being transferred. This data is useful for power system engineers to determine the cause of faults and stability of power system. Therefore the total condition of power system at each area can be supervised, protected and governed with the help of PMU based measurement of parameters.

2.1. PHASOR REPRESENTATION OF SINOSOIDAL QUANTITY

We know that the sine wave is represented by equation (1), where the fundamental frequency can be either 50Hz or 60 Hz depending on the location [15].

$$x(t) = \sqrt{2}X sin(\omega t + \emptyset) \quad (1)$$

Where, ω is the frequency of sine wave in rad/sec and ϕ is the phase angle which is measured in radians. Now equation 1 can also be written in its phasor form having real and complex term as

$$x(t) = Re\{Xe^{j(\omega t+\emptyset)}\} = Re[\{e^{j(\omega t)}\}Xe^{j\emptyset}] \quad (2)$$

Again it can be re written as

$$X^{*} = Xe^{j\emptyset} = X[cos\emptyset + jsin\emptyset] \quad (3)$$

Graphically this sinusoidal equation can be plotted as shown in figure 1

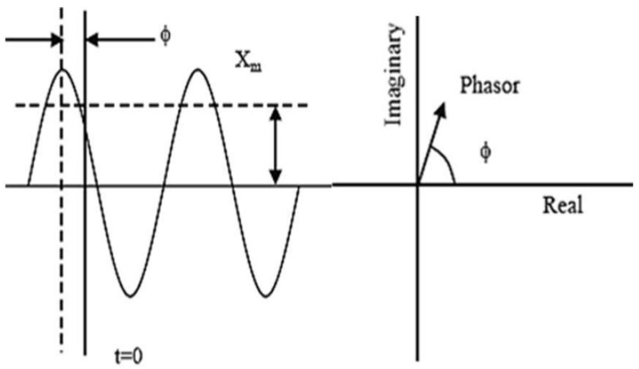

Figure -1: Sinusoidal wave and its phasor representation

2.2. BLOCK DIAGRAM OF PHASOR MEASUREMENT (PMU)

The real time measurement of synchronized phasors of phase angle and magnitudes can be done with the help of PMU technology. The block diagram of PMU technology is shown in figure 2, where two analog inputs mainly voltage and current are obtained from the instrument transformers secondary windings (Current Transformer in care of current measurement and Potential Transformer in case of voltage measurement) [16]. Further the positive sequence components of both quantities are calculated with the help of sequence analyzer who's discrete Fourier transform is evaluated with the help of microprocessor.

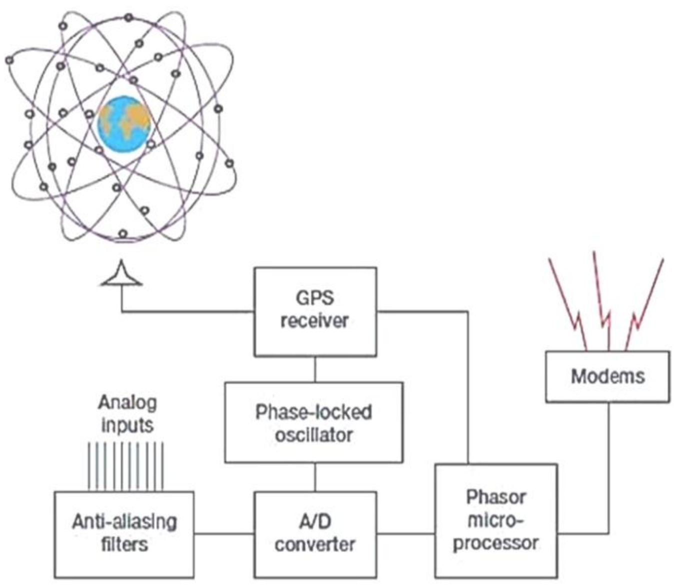

Figure -2: Block diagram of PMU

PMU consists of various components like anti-aliasing filters where all the noises which have been added in the signal during recording are to be eliminated. Further this noise free signal is given to analog to digital converter since all the data recorded is of analog type and microprocessor works on digital inputs [17]. The work of microprocessor is to perform the Fourier transform and determine the frequency components of voltage and current signals. Further if any corrective actions if required then it is commanded through GPS and modems.

2.3. WORKING OF PMU

The location of PMUs are best suited near the buses of feeder where time synchronized data is provided by PMUs with the help of GPS technology. These devices also assess the frequency and rate of change of frequency. The currents and voltages measurements are alleged on in general data relocate devices which are easy to get to from remote positions for indicative functioning. The phasor data assists in real time applications [18]. At the following stage, Phasor Data Concentrators (PDCs) is represented which collect and records the data, decline interpolated data and line up the time sticks from several PMUs. As PDCs have storage facilities, they have all PMUs data available in it. Other stage of hierarchy is called Super Data Concentrators (SDCs) having facility for data storage. The block diagram shown in the Figure 3 represents the hierarchy of PMUs and PDCs. Main flow of data is in the upward direction but some tasks have reverse direction communication capability [19].

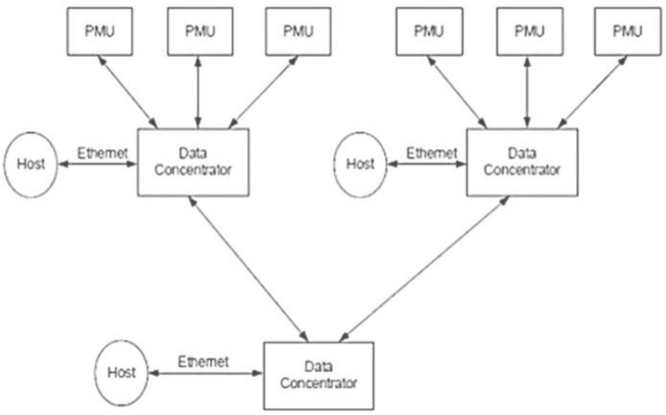

Figure -3: PMUs and PDCs hierarchy

2.4. PMU COMMUNICATION LINKS

To communicate the recorded data to the remote location there is a requirement of some communication system. Generally data is communicated in two form which are used for any communication task like channel capacity and channel latency which is used for the selecting communication link. Applications like diagnostic analysis require PMU data to help in approximating and canvassing the power system functioning during all major disruptions. The purpose was first served by the rented telephone circuits. When there is no data transfer latency, the switched telephone circuits are tried. But, currently the fibre-optic connections are used as it data transfer rate is very high."

3. APPLICATION OF PROPOSED PMU TECHNIQUE ON IEEE 5 BUS SYSTEM

The standard IEEE 5 bus system is shown in figure 4, here it is observed that all the 5 buses are interconnected to each other and are connecting different areas of power system.

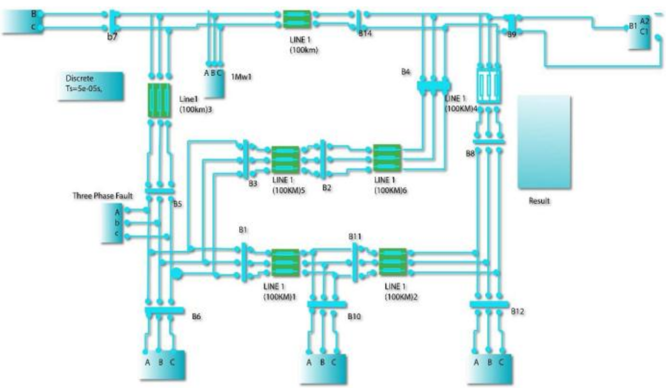

Figure -4: IEEE 5 bus system

The faults occurring on transmission are detected mainly by two components. As we know that whenever fault occurs in any network then the impedance of that system decreases to very low value and accordingly voltage also decreases, therefore the first component is the reduction in voltage [20]. Again as we are aware that current always flows through low resistance path and since during fault the impedance of circuit decreases drastically therefore the current starts to flow towards the direction of fault, therefore the other component is the flow of power. Here the direction of power flow is identified with the help of phase angle which is compares with the reference phasor angle. And therefore the direction of fault can be identified by comparing the phase angle of voltage and current of transmission line. The main idea of PMU technique is to detect the fault location. This is done by comparing the recorded or measured value of positive sequence voltage and current at main bus of each area. The advantage of doing this is that wherever the magnitude of voltage is less then the fault has occurred in that particular area. Again the differences in the values of positive sequence current angles are evaluated for all transmission lines connected with the faulted area. After calculating these angles with each other the maximum difference value is selected to identify the faulted line. The flowchart of the same is shown in figure 5.

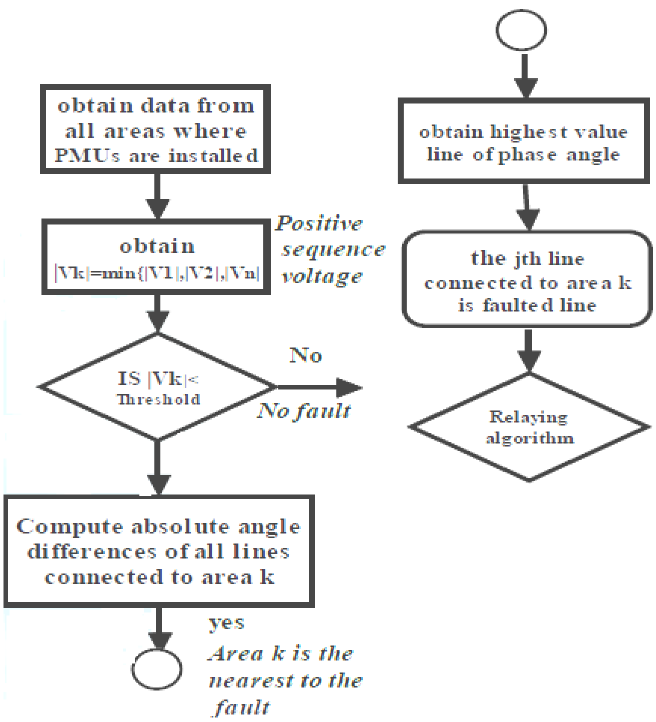

Figure -5: Flowchart of proposed PMU technique

4. RESULTS

To validate the results of the proposed technique simulation of IEEE 5 bus system is done using MATLAB / SIMULINK environment as shown in figure 6. The positive sequence components of voltage and current are recorded at each area of transmission network. After recording this positive sequence the magnitude of individual area is used to make decision. If the recorded magnitude is less than reference value then it is considered as the faulted area at the first step, in the next step for confirmation if the phase angle change with respect to reference phasor then it gives the final decision of faulted area.

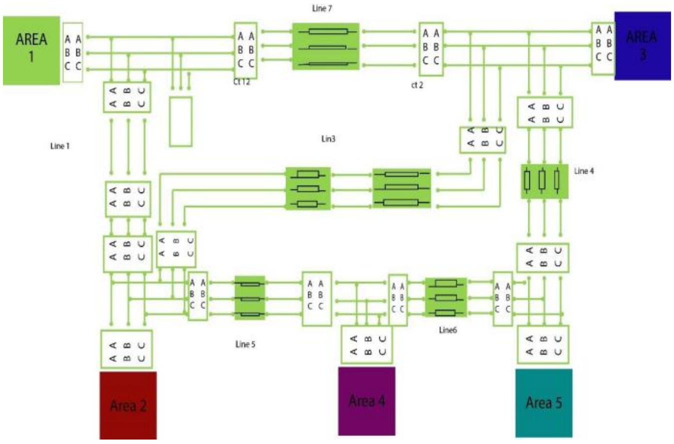

Figure -6: MATLAB simulation of 5 Bus system

Consider fault occurs in between area 1 and area 2 and the positive sequence voltages of affected areas as well as unaffected area is shown is shown in figure 7, 8 & 9

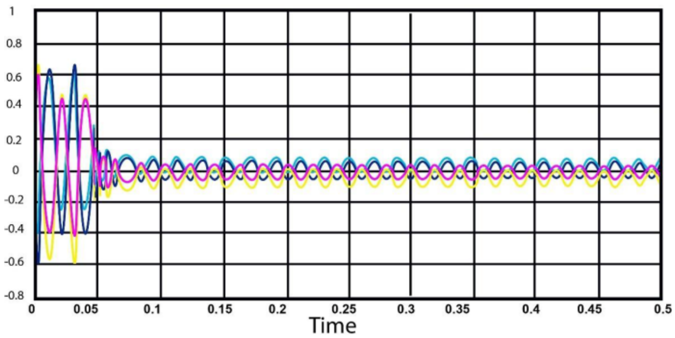

Figure -7: Three phase voltage at area 1

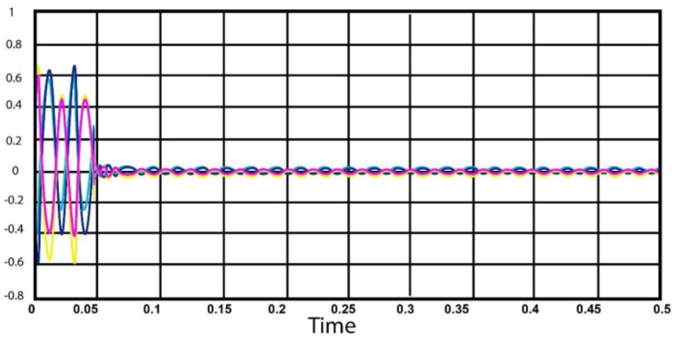

Figure -8: Three phase voltage at area 2

From figure 7 and 8 it is can be observed that the voltage level of area 2 is nearly equal to zero whereas the voltage level of area 1 is not equal to zero. So it can be considered that the fault has occurred near area 2. Also the three phase voltage of unaffected area is also reduced by some amount as shown in figure 9

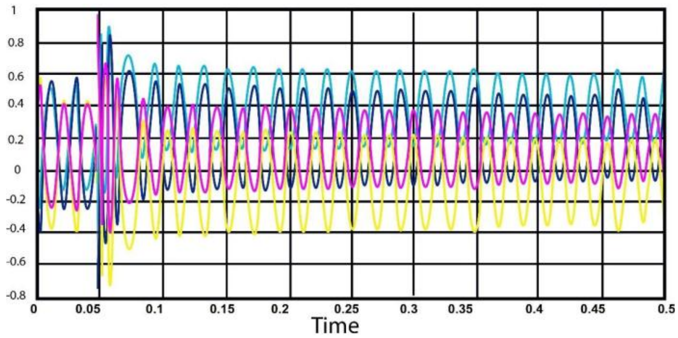

Figure -9: Three phase voltage at area 4

Also the current flowing through lines is shown in figure 10 and 11. Here it is noted that as soon as the fault occurs the magnitude of current suddenly increase to a higher value.

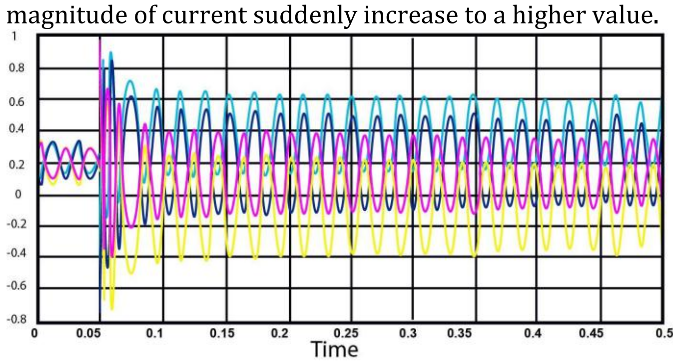

Figure -10: Three phase Current at faulted area 1

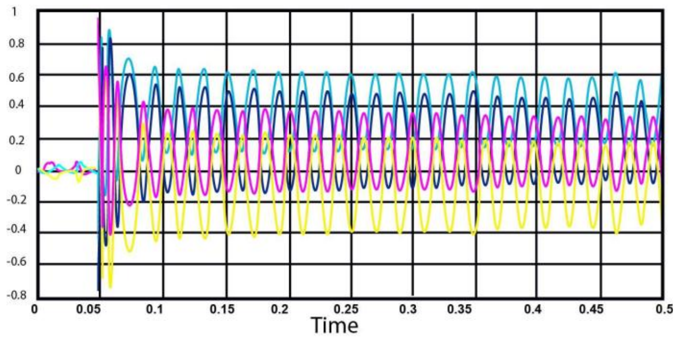

Figure -11: Three phase Current at faulted area 2

Further to give a final decision positive sequence analysis of both voltages and currents is shown in figure 12 and 13. Here it is observed that the positive sequence voltage at the faulted is very less as compared to healthy system. Further same results are seen from the analysis of positive sequence analysis of current

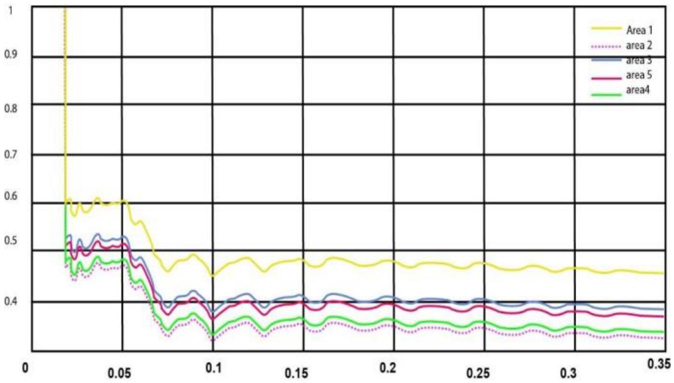

Figure -12: Positive sequence Voltage Magnitude

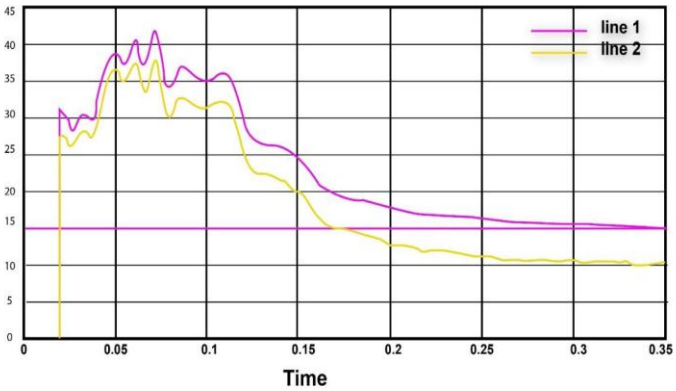

Figure -13: Positive sequence current angle

Similarly the analysis is done for double line to ground fault. The positive sequence voltage magnitude in case of double line to ground fault is shown in figure 14 whereas the positive sequence current angle for the same fault at same location is shown in figure 15

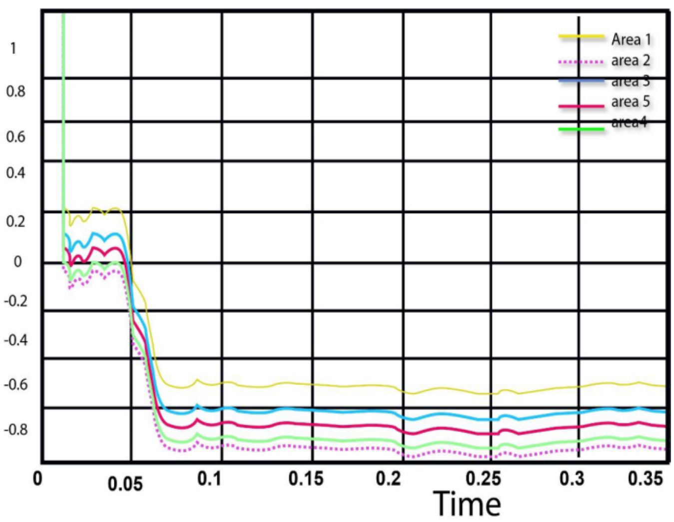

Figure -14: Positive sequence Voltage Magnitude

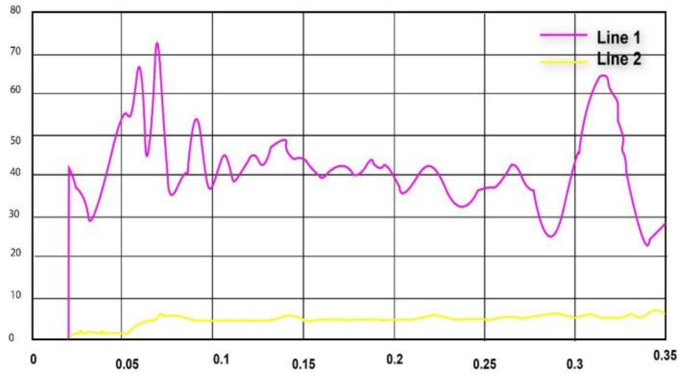

Figure -15: Positive sequence current angle

Similar analysis can be carried out for any type of fault whether it be a symmetrical fault or unsymmetrical one. And the same analysis can conclude the appropriate results.

6. CONCLUSIONS

The paper presents a new protection technique for transmission grids using phasor synchronized measuring technique in a wide area system. The protection scheme has successfully identified the faulted line all over the interconnect system. The algorithm uses the positive sequence voltage and current synchrophasor measured at each line end, and its main objective is to detect different fault locations. Unlike the present techniques, it provides reliable protection to the power system so that it can be applied to any practical power system. Test results from MATLAB simulation seems to be satisfactory. Positive sequence voltage magnitude method and positive sequence phase angle method proves the best technique for the fault analysis in smart grid. Therefore it is recommended to apply this concept on hardware basis.

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