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PMU PLACEMENT AND FAULT ELIMINATION IN POWER SYSTEM USING HYBRID IWD-GOAT ALGORITHM

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ABSTRACT

Power system fault currents are crucial since they determine the system's capacity to survive the failure. The fault currents may be measured in several methods. Phase voltages and phase currents are measured using the Phaor Measurement Unit (PMU). The faults that occur in power systems are more often unsymmetrical, and Line to line-to-ground faults are the ones that happen there the most frequently. In this study, a technique to compute fault currents in a PC and discover fault currents by monitoring the phase currents using PMU has been provided. If the computed fault current is higher than the stated limit, the relay coil is triggered. The outcomes of the simulation demonstrate the output's perfection.

Keywords: modified goat algorithm, PMU, LG fault, fault current elimination.

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1. INTRODUCTION

Fault currents, particularly long ones, destroy power systems. G.Witzenfield *et al.* adopted the double-sided elimination strategy to tackle the direct current in computer memory issue by considering the whole defective subsystem as a grounding network [1]. Using the ATP-EMTP, HanZeng *et al.* suggested a novel fault and arc model for flexible neutral grounding of the power system and discovered that this method mitigated inrush current at faulted points [2]. The novel approach described by J. Ran *et al.*, which is based on IGBT, was tested on EMT-TP[3] and shown to be effective in reducing faults in resonant earthing systems. To diagnose a High-resistance Ground issue in an adjustable speed drive, J. *et al.* devised a novel approach that does not rely on the expertise of a technician at all[4]. A.M. Ismail suggested a novel technique for improving differential protection in transformers; this approach was used in Egypt's El-Gamal Substation, where it was shown to decrease zero-sequence current[5]. [6] Zhang developed a three-phase fault emulator and a combination strategy to eliminate transients for simulation studies [7]. In their study of 240V systems, P.S. Haer *et al.* developed a new approach they named Ground Fault Current Interrupters, and they discovered that the new method was effective [8].

With the use of three test systems, G. Morales *et al.* suggested a novel method to eradicate the multiple estimates of fault location in radial power systems [9]. With the help of a hybrid algorithm of cuckoo search and evolutionary particle swarm optimisation algorithm with the fuzzy logic system, V. Gomathy *et al.* proposed a new integrated approach for fault diagnosis in three phase inverter circuits using discrete wavelet transform and principal component analysis [10]. A phasor measuring unit is a device for quantifying current phasors. Its positioning is an issue discussed in the literature, and several techniques have been used to solve it. The GA approach in [11] addresses the OPMUP problem by hinged different PMU location standards, such as the absence of basic measurements and sets from the network, the greatest amount of measurements obtained compared to the underlying one, the highest precision of evaluations, the lowest cost of PMU location, and the transformation of the organisational diagram into a tree.

The OPMUP issue was solved using a GA strategy in [12]. As part of a health checkup for the GA, we compared the assessor's estimates to the system's actual power flows and found significant discrepancies. The quantity of work related to wellbeing quadruples when PMUs are present. To ensure the fewest possible PMUs, [13] introduces a genetic algorithm (GA) process that chooses the least number and locations of PMUs, as well as the lowest amount of phasors predicted by a PMU. This certification adds a layer of credibility to the technique that is missing from alternatives that assume PMUs monitor phasor flows at all adjacent nodes. The strategy relies on the GA's systematic approach to its human resource management, which is a key component. This standardisation facilitates a quick and unobtrusive assessment of everyone's health status.

In [14], an NSGA is used to effectively balance the aims of decreasing PMUs and boosting measurement repetition rates. Optimisation doesn't utilise target inclinations. The leader chooses the best solution from the search cycle's output. The algorithm's key value is that it delivers the full Pareto-optimal front rather than just a single point arrangement and may be employed in many multi-target optimisation problems in a constrained enumerative search area. Differential evolution (DE) is an iterative optimisation method that seeks to enhance a candidate arrangement concerning a value proportion. Pareto non-dominated sorting and the differential evolution algorithm (NSDE) are brought together naturally in the method published in [15]. It can quickly and accurately grasp global multi-target optimisation, find several Pareto-optimal configurations, and finish the whole Pareto front. The methodology's PMU placement plans are flexible, comprehensive, standard, and logical. Deductive decision-making based on practical circumstances has fair informative relevance for the leader. In addition, the ideal application of the NSDE method to the PMU optimal placement problem with multiple targets, as well as other optimal problems in the design community, merits additional thought and investigation.

To discover a good solution to an optimisation problem, the approach of Simulated Annealing (SA) tries out several permutations on the present setup. The new arrangement is a worse variety, and its probability decreases as the computation progresses. The process is more likely to find an ideal or near-optimal arrangement the slower the cooling schedule or rate of diminishment. The recommended SA method in [16] proposes a fundamental objective function that factors in the cost of transport and installation of the measuring tools. In [17], the author introduces the concept of depth of unobservability and discusses its implications for the number of PMUs. Results from experiments show that this process ensures a dispersed deployment of PMUs throughout the network and that there isn't an overly great gap between undetected and detected buses. To solve the PMU placement problem brought on by realistic correspondence, the SA approach is used. To determine the influence-driven best PMU placement for system observability, the SA method is obtained in [18]. Each bus's border sensitivities are calculated using an observability geography study technique. Taking into account the concept of unobservability depth [16] is a natural extension of the aforementioned technique. In [19], we offer a stochastic simulated annealing (SSA) approach to solving the OPMUP problem in a way that guarantees topological observability. When PMUs are deployed, a measuring system emerges that lacks the most fundamental metrics. Even without any further measurements, the most fundamental system can identify terribly measured information. Punishment works that provide basic measuring recognised evidence are included. Similar advice is given in [20]. To solve the OPMUP problem, we use the SA method [21] to collect enough preliminary data hinged on SCADA and PMU readings to obtain all the state vector sections for load stream counts devoid of t cycles. In this case, there should be a very small number of PMUs.

In this study, we present a novel method for detecting fault currents by placing Phasor measurement units using a hybrid version of the Goat algorithm, tripping the power system when the fault current is too high. While an acceptable location for the phasor measuring unit was discovered.

2. PMU PLACEMENT PROBLEM FORMULATION

If the phase currents and voltages of a power system can be measured, then this additional requirement will make the power system visible. In this case, IEEE 14 bus architecture is considered. The following solution is provided for the issue of PMU installation on this bus. Maximize the number of buses that are required to make the power system observable. It is represented by,

$$NPMUub=N+S23 \tag{1}$$

$\mathrm{N}_{\mathrm{PMU}}^{\mathrm{ub}} = \text{Upper bound of the number of PMUs}$
(2)

S= unknown injections

The ideal placement of the PMU requires the generation of a solution space. A lexicographic method is employed to provide a set of potential answers for this problem. The hybrid goat algorithm increases fragrance and dryness to optimise PMUs for the power plant vicinity. The following goal function is utilised, which both saves money and makes the system more easily observable.

$$Mini=1Ncpixi+i=1nj=1(cf.dij+cr.xi)j \tag{3}$$

St $A.X \geq b$
$$\boldsymbol{U{\in}Evyij= N{-}1} \tag{4}$$

$$\sum_{U\in E}^{v} y_{ij} \leq \boldsymbol{S} - \boldsymbol{1}, \forall\, \boldsymbol{S} \in \boldsymbol{V} \tag{5}$$

The objective function value should be assessed for cost and observability. The goal function's smell and dryness factors are changed. Each branch outage modifies the constraints:

$$Mini=1Ncpixi \tag{6}$$

St $A.X \geq b$
$\mathrm{A.X} \geq \mathrm{b}\ \ [2\ \ 2\ \ 2\ \ \ldots..2]^{\mathrm{T}}$
$$\boldsymbol{Aj.X{\geq}b\ \ 1.......1T\ j{=}1,,...Ntop} \tag{7}$$

Aj is called an adjacency matrix. It is changed due to branch outages. The smell factor values are updated based on solutions from (2). If the objective function is not the number of PMUs is to be increased by 1 and its location has to be eliminated from the list. If the objective function is satisfied, then the number of PMUs is lessened by, 1, and the smell factor is enhanced accordingly. This process is repeated for all combinations to get optimal placement of PMUs. An IEEE 14 bus system is given in Figure-1.

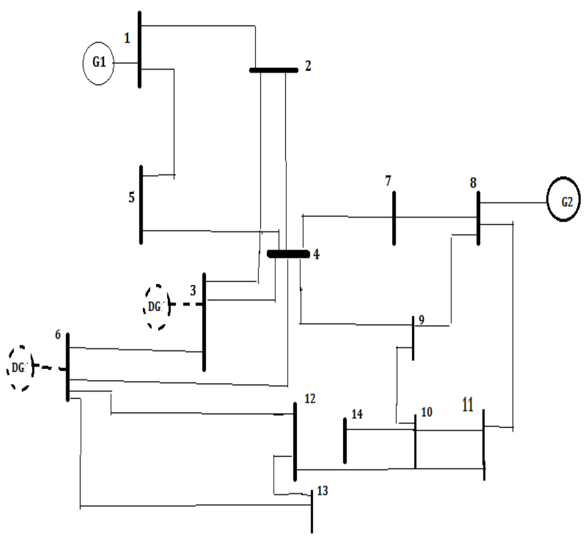

Figure-1. IEEE 14 bus system.

3. HYBRID IWD-GOAT ALGORITHM

Nature inspired the clever water drop algorithm. Rivers naturally choose the shortest way. There may be multiple perfect routes, but rivers always pick the one that best accommodates the movement and reaction between river drops and river bed drops. In this method, several synthetic water droplets follow a route with little dirt material. Soil quantity (hence referred to as soil) and water drop speed are the factors that define the best route. As the synthetic water droplets go along their journey, the soil and their speed adapt to their surroundings. Each water drop uses several different routes to go from its starting point to its final one; the intelligent water droplet algorithm does this. In this procedure, the final destination is occasionally unknown as well. However, it is our responsibility to reach the final destination. It is hypothesised that Intelligent Water droplets (IWD) travel along pathways of limited length.

The difference in IWD velocities between the two places is inversely related to their soil types. Therefore, to alter velocity for the third time, dirt is either added or withdrawn. In between two potential spots. Again, the soil quantity is related to the potential IWD travel time between two points. This length of time is encountered regularly.

In their research, Ayyappa Srinivasan *et al.* suggested a novel Goat method for removing harmonics [22]. Goats in Melakarandhai, a hamlet in the Thoothukudi district of Tamil Nadu State, India, use their sense of smell to locate the patch of grass with the highest concentration of forage and gorge them accordingly. They begin to graze wherever there is a more abundant supply of grass or food. The highest concentration of grass is where they find their grass-based diet.

The answers to the issue of congestion management may be found by making use of this trait and replicating it using fake goats. Our robotic goats traverse the solution space, which is partitioned into discrete sections. After determining that a solution fits the problem, they explore the spaces adjacent to the present solution space; if they discover a new solution that is more optimum, they discard the old one. The following are the stages of this algorithm.

A. Formulation of Solution Space

The continuous LMP solution space is sampled. Let 25 goats cross the solution space simultaneously. The solution space has a lower and upper value, li and ui, where i=1, 2, 3,........D is the number of variables. Randomly sample the solution space:

$$(j)=li+ui-li\,j-1+rand0,1 \quad (8)$$

Here Xi=solution space
J=1,2,3.......P with P is the number of goats.

Thus the sampling of solution space depends on the number of goats. For the sake of the accuracy of solutions, a number between 0 and 1 is added randomly.

Each solution has a certain "smell factor" ascribed to it. Grass does not cover the ground everywhere in nature. It has suddenly burst into existence. This means that areas of the ground where just dirt and no grass are present tend to be dry. The ideal solutions are also readily accessible. There could be no answers in that area. Therefore, the "dryness factor" is added to the "smell factor" to replicate this behaviour. In reality, this component is included with solutions to signal either that the solution is unsatisfactory or that it does not exist.

The Intelligent Water Droplet Algorithm discovered this pattern of river flow, which follows the areas with the least amount of river bed or dirt. In this case, this feature was implemented to speed up the solution process without compromising accuracy. The equation may find a satisfactory solution at higher levels of odor intensity. Since there are 25 goats in this scenario, the search area has been partitioned into 25 regions, with each goat looking in a different region. As a result, less time is spent computing. Then, information about the solution, aroma, and dryness is committed to long-term memory.

B. Movement

Goats behave in a way that is both probabilistic and deterministic. Where m is the total number of possible actions, P is the total number of goats, making this matrix of size mix P. Each goat can recall the taste, texture, and aroma of the prior solution.

C. Exploitation and Exploration

The iteration factor

f_i^k of a goat k for any ith variable is given by,

$$fik=1, if\ q<q0\ and\ j=j*0,\ \ if\ q<q0\ and\ j\neq j* \quad (9)$$

Where q is the random number between 0 and 1 and q_0 is the threshold parameter fixed for each iteration.

$$j*=\max(\alpha i1,\alpha i2,\alpha i3\ldots\ldots,\alpha ik) \quad (10)$$

The threshold value is fixed and hinged to obtain whether exploration is to be performed.

i) Exploitation: If $q < q_0$, the goat decides to make a local search that is searching the nearby solution to find a more accurate solution called fine tuning. The solution is fine-tuned by further exploiting the nearby solution space for a distance called radius "r_i".
Let the current solution obtained by

$$x=x1,2,\ x3\ldots\ldots xD\ \} \quad (11)$$

Now fine tuning of the solution is done in the distance or radius of r_i and the interval

$$xi-r,\quad xi+ri, \quad (12)$$

The value of ri is obtained as,

$$ri=ui-li2P \quad (13)$$

The solution obtained is increased or decreased or unchanged as per the following criteria:

$$xi\,new=\min xi+ri,\sigma i,,\ \ if\ \ 0<q<13xi,\ \ if\ \ 13<q<23\max xi-ri,\sigma i,li,if\ \ 23<q<1 \quad (14)$$

With σ is a random number between 0 and 1. This solution set obtained is evaluated. If the solution is better than the previous one then r_i has to be extended or otherwise, it has to be reduced. This process is repeated for "v "several times where v is the exploitation frequency determined initially.

ii) Exploration: When q>q0, that is when the solution in the area found does not satisfy the switching angle equations, the goat must be culled and the population size decreased by one. Meanwhile, more goats are doing their searches in the area. By not venturing into uncharted territory, you save yourself the trouble of dealing with goats.

D. Smell Factor

Goats in the wild investigate an area for a possible answer. If there is grass in the vicinity that smells better than where they are, they will migrate there. Similarly, our synthetic goats can detect a remedy based on the olfactory cues they are given. The solution must be discarded if it does not work. If it's a good fit, then it has a stronger synthetic odour. To do this, we include a value between 0 and 1 known as the fitness factor. The odorous factor in the business world is,

$$\alpha_i^{(j)} \leftarrow (1+\rho)j+\rho\alpha min \quad (11)$$

Where α_{min} is the minimum value of the smell factor and ρ is the fitness factor .i=1,2,3.....D and j=1,2,3.....P. Thus, in each iteration, the fit solutions are retained by increasing the smell factor, and the least fit ones are removed out.

To save time and space, the dryness factor is applied only during the first step of the process, when the solution is discarded. Figure-2 is a flowchart detailing the hybrid Goat algorithm.

4. PROPOSED SYSTEM

Figure-3 depicts a block schematic of the proposed system. The suggested system makes use of IEEE 14 bus architecture. The positioning of PMUs in that system is determined by the output of the Hybrid Goat method. A personal computer is fed data on the RYB phase currents that have been measured. Positive, negative, and zero sequence currents may all be calculated by the computer. When these currents are compared to set point values, actuation signals are generated that turn on the relay coils

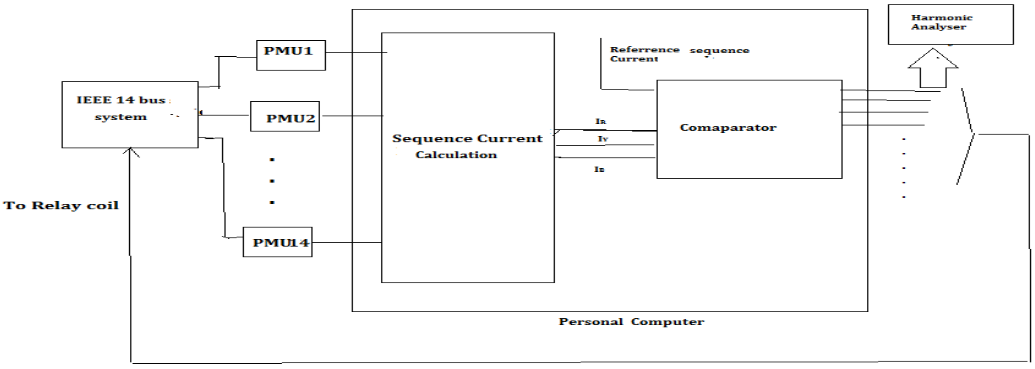

Figure-2. Block diagram.

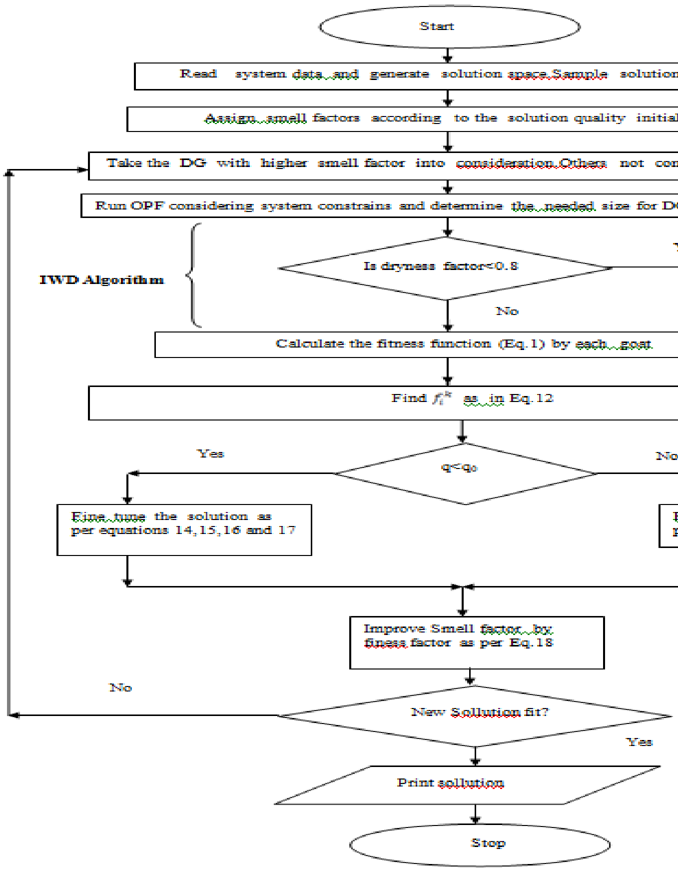

Figure-3. Flow chart of hybrid goat algorithm.

5. SIMULATION RESULTS

This IEEE 14 bus, IEEE 24 bus, and IEEE 30 bus system were simulated along with a hybrid goat algorithm in MATLAB, and optimal buses for placing the PMUs under Normal operating conditions were obtained. Table-I shows the results:

Table-1. Optimal PMU placement under normal operating conditions.

Bus System	Optimal PMU Location as per [23]	Number of PMUs	Optimal PMU Location as per proposed method	Number of PMUs
IEEE -14	2, 3, 5, 7, 9	5	2, 7, 9	3
IEEE -24	2, 7, 8, 10, 16, 19, 21, 23, 24	9	2, 12, 16, 23	4
IEEE-30	2, 3, 6, 9, 10, 12, 16, 24, 25, 29	10	2, 5, 9, 12, 23, 25	6

Table-2. Optimal PMU placement under bus outage conditions.

Bus System	Optimal PMU Location as per [23]	Optimal PMU Location as per proposed method
IEEE -14	(2,6) (2,9)	(2,6)
IEEE -24	(2,6) (2,10) (12,18),(16,21) (23,24)	(2,10) (16,21)
IEEE-30	(2,4) (2,6) (12,15) (21,22) (23,24)	(2,3) (12,14) (21,22)

It is not difficult to discover that there are 8 hubs with degree at least 3. Here K=8 and n=14. Thus, the quantity of PMUs required that is, the lone potential qualities for S somewhere in the range of 3 and 4 utilizing condition. Now the assignment is to discover the minimum number of PMUs, and the ruling set S. The essential thought of this algorithm is to test all conceivable hub blends by the perception rules until one mix is discovered to have the option to "notice" the system. A test requires a mix as a measurement. For the IEEE 14-bus system, the greatest number of measurements is the number of mixes produced by choosing quantities of a gathering in the middle of 3-4, who will join, will give the necessary number of PMUs in the system. It ought to be remembered that, in the execution of the algorithm, it isn't important to run all the measurements to discover the S-set. The quantity of measurement before we get the S-set can be any number. Table-3 shows the location of PMU using the hybrid goat algorithm.

Table-3. Location of PMU and number of PMU using hybrid goat algorithm.

Bus System	Location of buses	No. of PMUs
IEEE 14	2,4,5,7,8,10	14

Figure-4 shows the time required to reach the optimal number of PMUs using the Hybrid Goat algorithm. It is seen that within a few milliseconds, the algorithm reaches the optimal placement of PMUs.

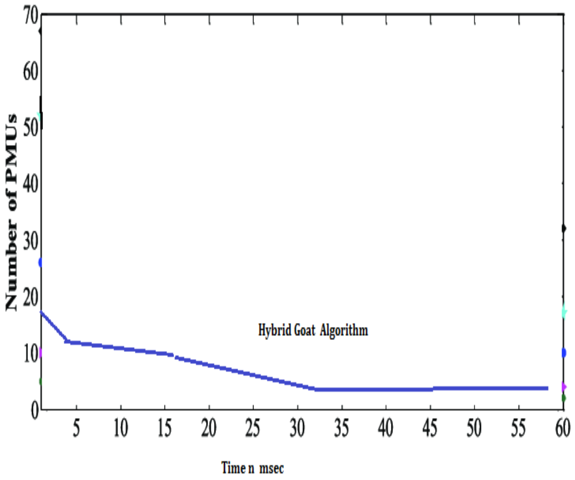

Figure-4. Speed of iteration of hybrid goat algorithm.

These results were given to another MATLAB M-M File with a Phaor measurement unit using a Sequence analyser. Accordingly, the IEEE-14 bus system with PMUs placed as per the results obtained was simulated. The phase currents under normal operating conditions in the system are shown in Figure-5.

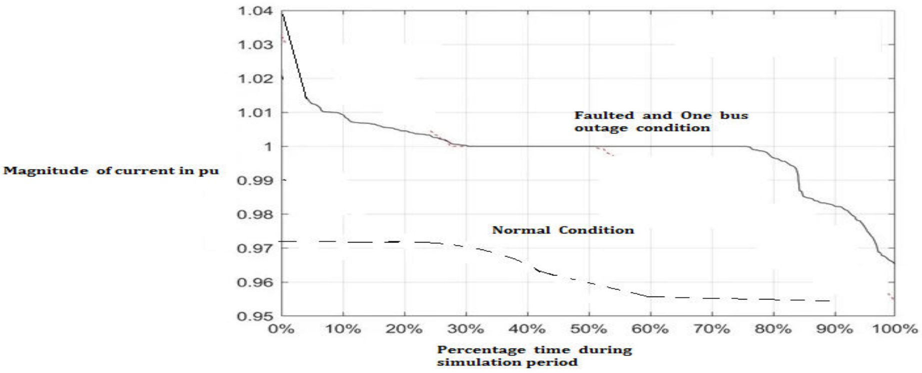

Figure-5. The currents are in normal and under faulted conditions.

A relay was introduced in the simulation to find the time at which the relay coil trips the phases when phase sequence currents under faulted conditions are above the limit. It was found that the relay coil trips the circuit to an off state in 9.23 msec. Figure-6 shows harmonic analysis obtained in the simulation of currents in the IEEE 14 bus system

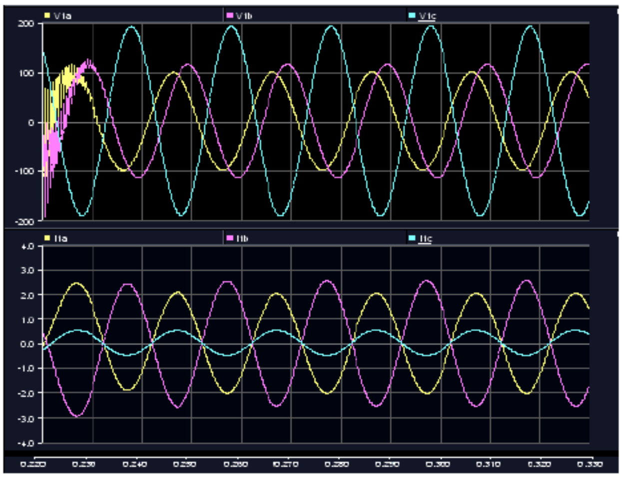

Figure-6. Harmonics of fault current in power system.

6. CONCLUSIONS

A three phase fault current measurement system by placing OMUs using the Goat algorithm along with fault current measurements and tripping the line if it exceeds the limit has been proposed in the paper. It is seen that the number of PMUs is less and they are placed optimally. Further, the relay coil trips off the circuit as per the outputs obtained from Phasor measurement units most quickly. Further work can be applied by using new algorithms.

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