CHAPTER – 1

Introduction

**Introduction**

**1.1 About Project Report**

This document is intended for everybody interested in technical aspects of Protection of power system using wavelet analysis. In this document we covered the different aspects such as transmission line parameters, protection of DG systems, brief description of wavelets and the test results what we have obtained in this project work. In this report we proposed a reliable threshold value for different phases of distribution networks with distributed generation.

**1.2 Transmission line parameters**

**1.2.1 Resistance:**

The electrical resistance of an electrical conductor is the opposition to the passage of an electric current through that conductor, the inverse quantity is the electrical conductance, the ease at which an electric current passes. Electrical resistance shares some conceptual parallels with the mechanical notion of friction. The SI unit of electrical resistance is the ohm (Ω), while electrical conductance is measured in Siemens (S). An object of uniform cross section has a resistance proportional to its resistivity and length and inversely proportional to its cross-sectional area. All materials show some resistance, except for superconductors, which have a resistance of zero. The resistance (R) of an object is defined as the ratio of the voltage across it (V) to current through it (I), while the conductance (G) is the inverse:

R=V/I  **;** G=I/V

**1.2.2: Inductance**

For medium and long distance lines the line inductance (reactance) is more dominant than resistance. The value of current that flows in a conductor is associated with another parameter, inductance. We know that a magnetic field is associated with a current carrying conductor. In AC transmission line this current varies sinusoidally, so the associated magnetic field which is proportional to the current also varies sinusoidal. This varying magnetic field induces an emf (or induced voltage) in the conductor. This emf (or voltage) opposes the current flow in the line.

This emf is equivalently shown by a parameter know as inductance. The inductance value depends upon the relative configuration between the conductor and magnetic field. Inductance in simple language is the flux linking with the conductor divided by the current flowing in the conductor. In the calculation of inductance the flux inside and outside of the conductor are both take care of.

The inductance so obtained is total inductance. Now onwards if not mentioned then inductance means total inductance due to conductor internal and external flux linkages. The symbol L is used universally to represent inductance. L is measured in Henry (H). It is usually expressed in smaller unit, milli Henery (mH). Manufactures usually specify inductance value per kilometer or mile.

The conductor inductance is

**L= 2\*10-7 ln (D/r)**

**1.2.3: Capacitance**

Capacitance is the ability of a body to store an electrical energy .Any object that can be electrically charged exhibits capacitance. A common form of energy storage device is a parallel plate capacitor. In a parallel plate capacitor, capacitance is directly proportional to the surface area of the conductor plates and inversely proportional to the separation distance between the plates. If the charges on the plates are +q and –q, and V gives the voltage between the plates, then the capacitance C is given by

C =

**1.3: What is Distribution generation?**

Distribution generation is an approach that employs small-scale technologies to produce electricity close to the end users of power. DG technologies often consist of modular (and sometimes renewable-energy) generators, and they offer a number of potential benefits. In many cases, distributed generators can provide lower-costs electricity and high power reliability and security with fewer environmental consequences than can traditional power generators.

In contrast to the use of a few large scale generating stations located far from load centers—the approach used in the traditional electric power paradigm—DG system employ numerous, but small plants and can provide power onsite with little reliance on the distribution and transmission grid. DG technologies yield power in capacities that range from a fraction of a kilowatt [kW] to about 100 megawatts [MW].Utility-scale generation units generate power in capacities that often reach beyond 1,000 MW. Distributed Generation (DG) is predicted to play an increasing role in the electric power system of the near future.

**1.4 Types of distributed energy sources**

Distribution energy resource (DER) systems are small-scale power generation technologies (typically in the range of 3 kW to 10,000kW) used to provide an alternative to or an enhancement of the traditional electric power system. The usual problem with distributed generators is their high costs.

1. Solar panel
2. Wind turbine
3. Photo voltaic cell

**1.5: Problems of distribution generation in distributed systems**

1. **Power Flow Redistribution**

**“**Zero point” analysis – Most distribution system have a radial configuration, designed considering that power would only flow in one direction, namely from the substation to the loads.

In the presence of independent producers, this may change considerably and in some cases it is even possible that the substation is fed by the distribution generators, a circumstance that should be foreseen. One convenient way to characterize DG-feeder interaction on such feeders is called “zero point analysis.” This focuses on the point on the feeder (if it exists) where power flow is zero, due to the DG unit output. Distribution generation analysis cases fall into two categories, depending on the relation of the generation output to the feeder load [5].

DG power output is than the load downstream of its location. In this case the DG unit reduces power flow on all equipment between it and the substation, but makes no impact on the loadings on anything downstream from it. DG output is more than the load downstream of the DG location. Here, too the DG unit makes no substantial impact on the loadings of any equipment downstream from it, but it reverses some of the flow on the feeder from its location back toward the substation. Unless its output is greater than the load on the entire feeder, it creates a “zero point” between it and the substation, where current flow is zero due to the back flow from the DG.

In general, the closer the zero point is to the substation, the greater the potential distribution capacity requirement reduction wrought by the DG, but the greater the potential for significant and complicated impacts with operating dynamics and protection needs. In cases where the DG output exceeds the load on the entire feeder, the zero point is essentially upstream of the feeder source at the substation. In these and some other cases, depending on the amount of DG output, loadings on some points of the feeder could be higher than in the non-DG case. Typically the highest loading on the feeder in these case is immediately upstream of the DG unit site, and the site is far “downstream” from the substation, it is typically for this portion of the feeder to see an increase in both normal loading and faulty duty, too.

**2) Fault Analysis**

The fault contribution from a single small DG unit is not large, however, the aggregated contributions from many small units, or a few large units, can significantly alter the short circuit levels and cause fuse-relay or fuse-fuse in coordination. This could affect the reliability and safety of the distribution system. In this context, it may be necessary to make adjustments in the protection schemes, changing relay settings or replacing or adding new relay and other protective devices, in order to guarantee the integrity and reliability of the system.

It is also imperious to verify how harmful the new fault currents can be and if they flow towards the substation. The contribution of the generators for the fault currents is more significant in urban system with low impedance circuits, than in rural systems, where the fault levels are typically smaller, and this contribution does not usually cause problems.

Due to the elevation of the fault levels, the capacity of interruption of switching equipment should be verified for that new operation point, to guarantee their suitable operation when demanded. In case the replacement of circuit breakers or switches is necessary, the analysis of the short circuit level is essential for specifying those Salman and Rida analyses dynamic aspects of the insertion of distributed generation using EMPT (Electro- Magnetic Transient Program) to simulate a distribution system with and without embedded generators.

They concluded that the critical clearing time (CCT) when a disturbance occurs in a system with embedded generation is much smaller than the clearing time in the absence of embedded generation. If a fault lasts longer than the CCT in a system with asynchronous generator, it would lose its synchronism with the network. In case of an induction generation, it would draw high inrush currents from the network until the over speed or other protection interrupted the fault.

**3) Protection Coordination**

Radial distribution systems, usually employ non-directional over current relays (inverse or definite time), reclosers and switches fuses in their protection systems. As these devices do not consider the flow direction, they may fail in cases when distribution generators contribute to the fault. A form of evaluating the protection coordination is through the analysis of the time vs current curves of the devices involved in the part of the network where the fault occurred.

The primary protection is the one closest to the fault point and backup protection is the next between the fault and the source (substation or distributed generator). Backup protection should interrupt the fault only in cases when the primary fails to operate.

It is important to remember that the utility objective is to maintain the load supply as long as possible, but the independent generator aims to protect its equipment from damage caused by the external system , so they must reach an agreement in questions related to low frequently/load curtailment situations or reclosing operations.

CHAPTER – 2

Literature survey

**LITERATURE SURVEY**

Distributed Generation (DG) is predicted to play an increasing role in the electric power system of the near future. Distributed generation is by definition that which is of limited size (roughly 10 MW or less) and interconnected at the bus station, distribution feeder or customer load levels. DG technologies include photovoltaic, wind turbines, fuel cells, sterling-engine based generators and internal combustion engine-generators. These technologies are entering a period of rapid expansion commercialization.

For example, commercial-grade residential-scale fuel cells will arrive within the next 2 or 3 years with expectations of millions of installed units within the next 10 years. Photovoltaic programs are aggressively growing with plans to have nearly one million roof tops equipped with PV within a decade. Wind farms are springing up worldwide with more than 4500 MW of wind capacity to be installed in the year 2014 alone. Even conventional internal combustion engine-generator and small gas turbine installations are increasing as commercial industrial electricity users install them for reliability and peak shaving applications. In fact, studies have predicted that distributed generation may account for up to 23% of all new generation going online by the year 2013. With so much new distributed generation being installed, it is critical that the power system impacts be assessed accurately so that these DG units can be applied in a manner that avoids causing degradation of power quality, reliability and control of the utility system.

The connection of distributed generators directly to distribution systems has become a common practice worldwide. Spier et al. [1] list some motivations for the increase in interest in the Distributed Generation:

* The possibility of decentralised operation of independent producers connected directly to distribution systems, reducing costs.
* Environmental aspects reinforce the tendency of generating small blocks or electricity.
* Power through renewable sources as small hydroelectric plants (PCHs), Eolic generators, photovoltaic panels, etc.

Besides several electrical benefits come from the connection of distributed generation to the distribution systems, such as [1] & [2]

* Emergency backup using during sustained utility outages.
* Value of energy savings through peak saving during time of use rates and/or curtail able periods.
* Reduced voltage sags
* Potential utility capacity addition deferrals
* Reduction of electrical losses
* Improves the power factor of feeders with the liberation of service capacity and
* Support the local load during islanding.

In the same way that the distributed generators bring benefits, they have a potential of significant impact on the operation, protection and control of the distribution or transmission systems. The introduction of these generators implies load current distribution, increases fault currents, and may also cause overvoltage problems. Thus, a fundamental requirement to approve their connection is a good coordination between the protection schemes of the independent generators and the utility [3].

The coordination of protection of devices aims to maintain the selectively among the devices involved in several fault possibilities, in order to assure the safe operation and reliability of the electric system [4]. In an efficient and coordinated protection system, faults are eliminated in the smallest possible time, isolating the smallest part of the system containing the cause of the fault.

In that way, the impacts of the insertion of distributed generation in the protection coordination, through the use of the computational tool SiGDist – Simulator of Distribution coordination [2].

The connection of distributed generators (DG) to distribution networks also influences the performance of the networks and the impact depends upon the number, location and size of injected DG. The presence of distributed generators in the distribution network can cause the mis-coordination of the system [3]. In order to overcome this problem, one can change the relay setting based on the number and location of DGs in the network. Another approach is selected in which, the capacity of DG at each mode is determined in such a way, and that the mis-coordination does not happen.

The above method is explained in two cases. In the first case, just one DG at each node is considered, but in the second case existence of two or more DGs in separate nodes is taken into account. The simulation result is presented and discussed in a typical distribution network. The application of wavelet transforms for the detection, classification and location of faults on transmission lines is demonstrated in [4].

A global positioning system synchronizing clock is used to sample three phase voltage and current signals at both ends of the transmission line over a moving window length of half cycle. The current signals are analysed with Haar wavelet to obtain detail coefficients of single decompositions. Fault indices are calculated from based on the sum of detail coefficients, and compared with threshold values to detect and classify faults. For estimation of fault location feed forward artificial neutral networks are employed. Two types of neutral networks are proposed, one for locating the phase faults and the other for ground faults. The proposed algorithm is tested for different locations and types of faults as well as for various incidence angles and fault impedances. The algorithm is proved to be efficient in detecting, classifying and locating faults [5].

CHAPTER- 3

Wavelets

**Wavelets**

* 1. **INTRODUCTION**

A wavelet is a wave-like oscillation with amplitude that begins at zero, increases, and then decreases back to zero. It can typically be visualized as a "brief oscillation" like one might see recorded by a seismograph or heart monitor. Generally, wavelets are purposefully crafted to have specific properties that make them useful for signal processing. Wavelets can be combined, using a "reverse, shift, multiply and integrate" technique called convolution, with portions of a known signal to extract information from the unknown signal.

As a mathematical tool, wavelet s can be used to extract information from many different kinds of data, including- but certainly not limited to – audio signals and images. Sets of wavelets are generally needed to analyze data fully.

A set of complementary wavelets will deconstruct data without gaps or overlap so that the decomposition process mathematically reversible. Thus, sets of complementary wavelets are useful in wavelet based compression/decompression algorithms where it is desirable to recover the original information with minimal loss. In formal terms, this representation is a wavelet series representation of a square-integrable function with respect to either a complete, orthonormal set of basic functions, or an over complete set or frame, for the Hilbert space of square-integrable functions.

* 1. **WAVELET THEORY**

Wavelet theory is applicable to several subjects. All wavelet transforms may be considered forms of time-frequency representation for continuous-time (analog) signals and so are related to harmonic analysis. Almost all practically useful discrete wavelet transforms use discrete-time filter banks. These filter banks are called the wavelet and scaling coefficients in wavelets nomenclature.

These filter banks may contain either finite impulse response (FIR) or infinite impulse response (IIR) filters. The wavelets forming a continuous wavelet transform (CWT) are subject to the uncertainty principle of Fourier analysis respective sampling theory: Given a signal with some event in it, one cannot assign simultaneously an exact time and frequency response scale to that event.

The product of the uncertainties of time and frequency response scale has a lower bound. Thus, in the scaleogram of a continuous wavelet transform of this signal, such an event marks an entire region in the time-scale plane, instead of just one point. Also, discrete wavelet bases may be considered in the context of other forms of the uncertainty principle.

Wavelet transforms are broadly divided into three classes:

* + 1. Fourier analysis to wavelet analysis
    2. Continuous wavelet transform
    3. Different properties of signals

**3.2.1 Fourier Analysis to Wavelet Analysis**

**Fourier Transform**

Fourier analysis is used as a starting point to introduce the wavelet transforms, and as a benchmark to demonstrate cases where wavelet analysis provides a more useful characterization of signals than Fourier analysis.

Mathematically, the process of Fourier analysis is represented by the Fourier transform

F (ω) =dt

For each value of ω, the integral (or sum) over all values of time produces a scalar, F(ω), that summarizes how similar the two signals are. These complex-valued scalars are the Fourier coefficients. Conceptually, multiplying each Fourier coefficient, F(ω), by a complex exponential (sinusoid) of frequency ω yields the constituent sinusoidal components of the original signal.

Graphically, the process looks like

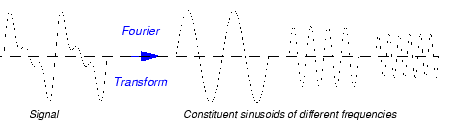


Fig: 3.2.1 Fourier transformed signal

**3.2.2 Continuous wavelet transforms**

Like the Fourier transform, the continuous wavelet transform (CWT) uses inner products to measure the similarity between a signal and an analyzing function. In the Fourier transform, the analyzing functions are complex exponentials, . The resulting transform is a function of a single variable, ω. In the short-time Fourier transform, the analyzing functions are windowed complex exponentials, ω (t), and the result in a function of two variables. The STFT coefficients, F (ω,t) represent the match between the signal and a sinusoid with angular frequency ω in an interval of a specified length centered at τ.

In the CWT, the analyzing function is a wavelet, ψ. The CWT compares the signal to shifted and compressed or stretched versions of a wavelet. Stretching or compressing a function is collectively referred to as dilation or scaling and corresponds to the physical notion of scale.

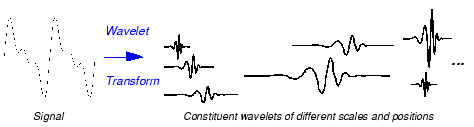


Fig: 3.2.2 Continuous wavelet transformed signal

**3.2.3 Different Properties of signals**

**1. Scaling:**

Like the concept of frequency, scale is another useful property of signals and images. In order to explain the concept of "stretching" or "shrinking" we introduce the scale factor, often denoted by the letter a.

The scale factor is a inherently positive quantity, a>0. For sinusoids, the effect of the scale factor is very easy to see.

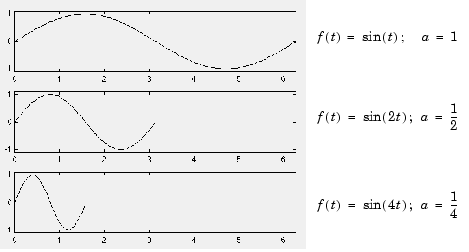


Fig: 3.2.3(a) Representing the scaling of sinusoidal signal

The scale factor works exactly the same with wavelets. The smaller the scale factor, the more "compressed" the wavelet.

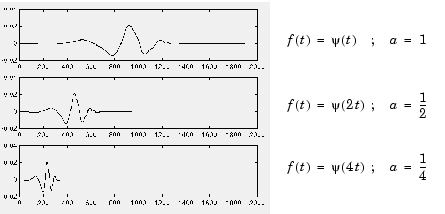


Fig: 3.2.3(b) Signals representing the scaling of wavelets

**2. Shifting:**

Shifting a wavelet simply means delaying (or advancing) its onset. Mathematically, delaying a function f(t) by k is represented by f(t – k):

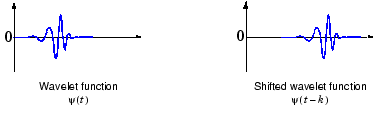


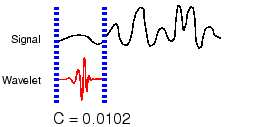
Fig: 3.2.3 (c) Signals representing the shifting property

**Five Easy Steps to a Continuous Wavelet Transform:**

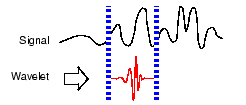
Here are the five steps of an easy recipe for creating a CWT:

1. Take a wavelet and compare it to a section at the start of the original signal.

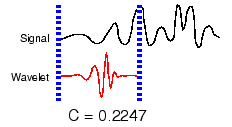
2. Calculate a number, C, that represents how closely correlated the wavelet is with this section of the signal. The larger the number C is in absolute value, the more the similarity. This follows from the fact the CWT coefficients are calculated with an inner product. See Inner Products for more information on how inner products measure similarity. If the signal energy and the wavelet energy are equal to one, C may be interpreted as a correlation coefficient. Note that, in general, the signal energy does not equal one and the CWT coefficients are not directly interpretable as correlation coefficients.



3. Shift the wavelet to the right and repeat steps 1 and 2 until you've covered the whole signal.



1. Scale (stretch) the wavelet and repeat steps 1 through 3



1. Repeat steps 1 through 4 for all scales.

**3.3. TYPES OF WAVELETS**

**3.3.1 HAAR WAVELET**

The **Haar wavelet** is a sequence of rescaled "square-shaped" functions which together form a wavelet family or basis. Wavelet analysis is similar to Fourier analysis in that it allows a target function over an interval to be represented in terms of an orthonormal function basis. The Haar sequence is now recognised as the first known wavelet basis and extensively used as a teaching example.

The **Haar sequence** was proposed in 1909 by Alfred Haar. Haar used these functions to give an example of an orthonormal system for the space of square-integrable functions on the unit interval [0, 1]. The study of wavelets, and even the term "wavelet", did not come until much later. As a special case of the Daubechies wavelet the Haar wavelet is also known as **D2**.

The Haar wavelet is also the simplest possible wavelet. The technical disadvantage of the Haar wavelet is that it is not continuous, and therefore not differentiable. This property can, however, be an advantage for the analysis of signals with sudden transitions, such as monitoring of tool failure in machines.

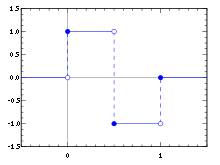
[](http://en.wikipedia.org/wiki/File:Haar_wavelet.svg)

Fig 3.3.1 Haar wavelet

**3.3.2 DAUBECHIES WAVELET**

Ingrid Daubechies, one of the brightest stars in the world of wavelet research, invented what are called compactly supported orthonormal wavelets — thus making discrete wavelet analysis practicable.

The names of the Daubechies family wavelets are written **dbN,** where N is the order, and db the "surname" of the wavelet. The db1 wavelet, as mentioned above, is the same as Haar wavelet. Here is the wavelet functions psi of the next nine members of the family:

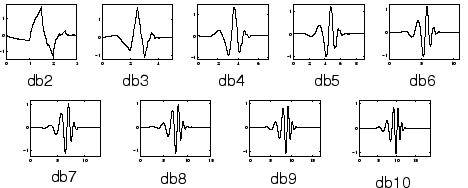


Fig: 3.3.2 Daubechies wavelet

**3.3.3 BIORTHOGONAL WAVELET**

This family of wavelets exhibits the property of linear phase, which is needed for signal and image reconstruction. By using two wavelets, one for decomposition (on the left side) and the other for reconstruction (on the right side) instead of the same single one, interesting properties are derived.

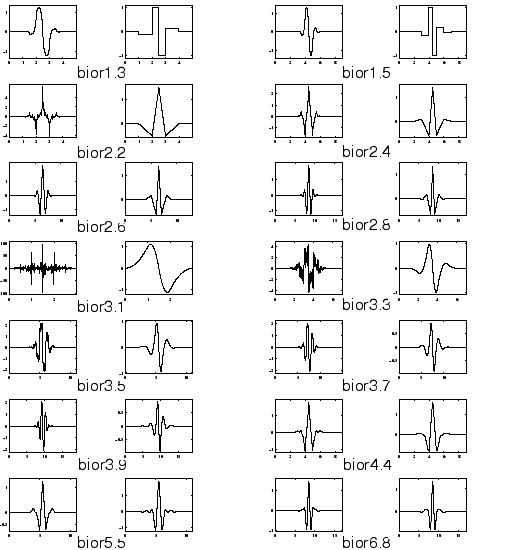


Fig: 3.3.3 Biorthogonal wavelet

**3.3.4 COIFLETS WAVELETS**

Built by I. Daubechies at the request of R. Coifman. The wavelet function has 2N moments equal to 0 and the scaling function has 2N-1 moments equal to 0. The two functions have a support of length 6N-1.



Fig: 3.3.4 Coiflets wavelets

**3.3.5 SYMLETS WAVELETS**

The symlets are nearly symmetrical wavelets proposed by Daubechies as modifications to the db family. The properties of the two wavelet families are similar. Here are the wavelet functions psi.

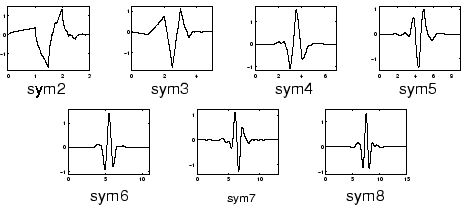


Fig: 3.3.5 symlets wavelets

**3.3.6 MORLET WAVELETS**

This wavelet has no scaling function, but is explicit.

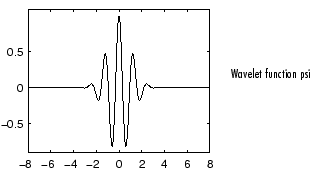


Fig: 3.3.6 Morlet wavelet

**3.3.7 MEXICAN HAT WAVELETS**

This wavelet has no scaling function and is derived from a function that is proportional to the second derivative function of the Gaussian probability density function.

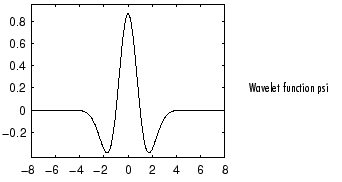


Fig: 3.3.7 Mexican hat wavelet

**3.3.8 MEYER WAVELETS**

The Meyer wavelet and scaling function are defined in the frequency domain.

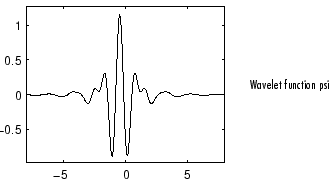
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Fig: 3.3.8 Meyer wavelet

**3.5 WAVELET DECOMPOSITION**

In wavelet analysis there are two components of the signal they are *approximations* and *details*. The approximations are the high-scale, low-frequency components of the signal. The details are the low-scale, high-frequency components.

The filtering process is shown in Fig

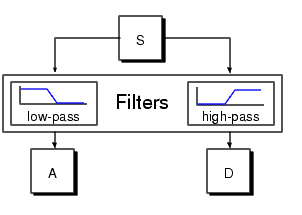
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Fig 3.3.2. Decomposition of the signal by filters

The original signal, S, passes through two complementary filters and emerges as two signals. Unfortunately, if we actually perform this operation on a real digital signal, we wind up with twice as much data as we started with.

Suppose, for instance, that the original signal S consists of 1000 samples of data. Then the resulting signals will each have 1000 samples, for a total of 2000.

These signals A and D are interesting, but we get 2000 values instead of the 1000 we had. There exists a more subtle way to perform the decomposition using wavelets. By looking carefully at the computation, we may keep only one point out of two in each of the two 2000-length samples to get the complete information. This is the notion of downsampling.

**3.5 WAVELET APPLICATIONS**

Wavelets are characterized by scale and position. As a result, wavelets are useful in analyzing variations in signals and images, which are best characterized in terms of scale and position. To clarify them we try to untangle the aspects somewhat arbitrarily.

For scale aspects, we present one idea around the notion of local regularity. For time aspects, we present a list of domains. When the decomposition is taken as a whole, the de-noising and compression processes are center points.

**Scale Aspects:**

As a complement to the spectral signal analysis, new signal forms appear. They are less regular signals than the usual ones.

The cusp signal presents a very quick local variation. Its equation is tr with t close to 0 and 0 < r < 1. The lower r the sharper the signal.

To illustrate this notion physically, imagine you take a piece of aluminum foil; The surface is very smooth, very regular. You first crush it into a ball, and then you spread it out so that it looks like a surface. The asperities are clearly visible. Each one represents a two-dimension cusp and analog of the one dimensional cusp. If you crush again the foil, more tightly, in a more compact ball, when you spread it out, the roughness increases and the regularity decreases.

**Several domains use the wavelet techniques of regularity study:**

* Biology for cell membrane recognition, to distinguish the normal from the pathological membranes.
* Metallurgy for the characterization of rough surfaces.
* Finance for the analysis of nonstationary time series.
* In Internet traffic description, for designing the services size.

**Position (or Time) Aspects:**

Let's switch to position aspects. The main goals are:

* Rupture and edges detection
* Study of short-time phenomena as transient processes

As domain applications, we get:

* Industrial supervision of gear-wheel
* Checking undue noises in craned or dented wheels, and more generally in non-destructive control quality processes
* Detection of short pathological events as epileptic crises or normal ones as evoked potentials in EEG (medicine)
* SAR imagery
* Automatic target recognition
* Intermittence in physics

CHAPTER- 4

Power system protection

**Power system protection**

**4.1 Introduction**

During normal operating condition, current will flow through all elements of the electric power system within pre-designed value which are appropriate to these element ratings. Any power system can be analyzed by calculating the system voltages and currents under normal conditions.

Faults can be defined as the flow of current through an improper path which could cause equipment damage which will lead to interruption of power. In addition, voltage level will alternate which can affect the equipment insulation in case of an increase or could cause failure of equipment start-up if the voltage is below a minimum level. As result the electrical potential difference of the system neutral will increase. Hence people and equipment will be exposed to the danger of electricity which is not accepted

In order to prevent such an event, power system fault analysis was introduced. The process of evaluating the system voltages and currents under various types of short circuits called fault analysis which can determine the necessary safety measures and required protection system. It is essential to guarantee the safety of public. In order to maintain analysis of faults leads to appropriate protection settings which can be computed in order to select suitable fuse, circuit breaker size and type of relay.

The severity of the fault depends on the short circuit location, the path taken by fault current, the system impedance and its voltage level. In order maintain the continuation of power supply to all customers which is the core purpose of the power system existence, all faulted parts must be isolated from the system temporary by the protection schemes. When a fault exists within the relay protection zone at any transmission line, a signal will trip or open the circuit breaker isolating the faulted line. The complete this task successfully, fault analysis has to be conducted in every location assuming several fault conditions. The goal is to determine optimum protection scheme by determining the fault currents and voltages. In reality, the power system can consist of 1000 of buses which complicate the task of calculating these parameters without the use of computer software such as Mat lab.

**4.2 Types of feeders**

Distribution system is a part of power system, which is between distribution substation and the consumer. According to design considerations, the primary distribution system is classified into three types they are,

* Radial type distribution feeder.
* Loop type distribution feeder.
* Network type distribution feeder

**RADIAL TYPE DISTRIBUTION FEEDER:**

Most distribution systems are designed as radial distribution system as shown in figure the radial system characterized by having only one path between each customer and a substation. The electrical power flows exclusively away from the substation and out to the customer along a single path, which, if interrupted results in compete loss of power to the customer. Radial design by far, is the most widely used form of distribution design, accounting for over 99% of all distribution construction in India. Its predominance is due to two over whelming.

Each radial feeder serves a definite service area. Most radial feeder systems arebuilt as networks, but operated radially by opening switches at certain points throughout the physical networks shown in figure, so that the resulting configuration is electrically radial. The planner determines the layout of the network and the size of each feeder segment in that network and decides where the open points should be for proper operation as a set of radial feeders.

The other type of radial primary feeder with express feeder and back feed is as shown in fig. The section of the feeder between the substation LV bus and the load center of the service area is called express feeder, from which no sub feeders or laterals will be allowed to tap off. The portion from load center towards the substation is called back feed portion. However, a sub feeder is allowed to provide a back feed towards the substation from the load center.

Most of the utilities in developed countries are using single and two phase laterals to deliver power over short distances by tapping off only one or two phases of the primary feeder minimizing the amount of wire that need be strong for the short segments required to get the power in general vicinity of few customers. Each service transformer in this system feed power into a small radial system around it.

Regardless of whether it uses single phase lateral or not, the advantages of the radial system, in addition to its lower cost, are the simplicity of analysis and predictability for performance. Because there is only one path between each customer and the substation, the direction of power flow is absolutely certain. Equally important is that the load on any branch of the system can be determined in the most straight forward manner by simply adding up all the customer loads “downstream” from that piece of equipment. Before the advent of economical and widely available computer analysis, this was only an overwhelming advantage. Simple, straight forward, “back of the envelope” design procedures can be applied to the distribution system with confidence at the resulting system would work well. The simplicity of analysis and confidence that operating behavior is strictly predictable are major advantages.

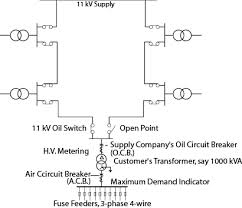


Fig. 4.2.1 Radial type feeder

**LOOP TYPE DISTRIBUTION FEEDER:**

An alternative to purely radial feeder design is a loop system as shown in fig. consisting of a distribution design with two paths between the power sources and every customer. Equipment is sized and each loop is designed so that service can be maintained regardless of where an open point might be on the loop. Because of these requirements, whether operated radially or with closed loops, the basic equipment capacity requirements of the loop feeder design do not change.

In terms of complexity, a loop type distribution system is only slightly more complicated than a radial system, power usually flows out from both sides toward the middle. Voltage drop, sizing and protection engineering are slightly more complicated than radial system

But if designed thus and if the protection is also built to proper design standards the loop system is more reliable than redial system. Service will not be interrupted to the majority of customers whenever a segment is out of service, because there is no “downstream” portion of any loop. The major of loop system is capacity and cost. A loop must be able to meet all power and voltage drop requirements when fed from only one end, not both. It needs extra capacity on each end and the conductor must be large enough to handle the power and voltage drop of the entire feeder, if fed from either end. This makes the loop system inherently more reliable than a radial system, but the larger conductor and extra capacity increase cost.

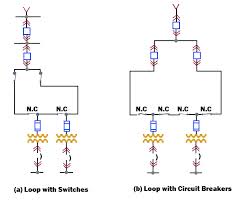


Fig.4.2.2 Loop type feeder

**NETWORK TYPE DISTRIBUTION SYSTEM:**

Distribution network is the most complicated; the most reliable and even in very rare cases also it is the most economical method of distributing electric power. A network involves multiple paths between all points in the network as shown in fig. power flow between any two points is usually split among several paths and if a failure occurs it instantly and automatically re-roots itself.

Rarely in a distribution network primary voltage level network design is involved, in which all or most of the switches between feeders are closed so that the feeder system is connected between substations. This is seldom done because it proves expensive and often will not work well. Instead, a “distribution networks” almost always involves “interlaced” radial feeders and a network secondary system a grid of electrically strong conductor connecting all the customers together at utilization voltage. Most distribution network networks are underground simply because they are employed only in high density areas, where over head space is not available.

The reliability and the quality of service of the network type distribution arrangement are much higher than the radial and loop arrangements. However, it is more difficult to design and operate than the radial or loop type systems.

**4.3 Types of faults**

There are two types of faults which can occur on any transmission lines;

1. Balanced faults
2. Unbalanced faults.

In addition, unbalanced faults can be classified into

1. single line-to-ground faults,
2. Double faults
3. Double line-to-ground faults.

The most common types of taking place in reality are as follow:

***Line-to-ground fault****:* This type of fault exists when one phase of any transmission lines establishes a connection with the ground either by ice, wind, falling tree or any other incident. 70% of all transmission lines faults are classified under this category.

***Line-to-line fault***: As a result of high winds, one phase could touch another phase and line-to-line faults takes place. 15% of all transmission lines faults are considered line-to-faults.

***Double line-to-ground:*** Two phases will be involved instead of one at the line-to-ground faults scenarios. 10% of all transmission lines faults are under this type of faults.

***Three phase fault:*** In this case, falling towers, failure of equipment or even a line breaking and touching the remaining phases can cause three phase faults. In reality, this type of fault not often exists which can be seen from its share of 5% of all transmission lines faults.

In order to analyze any unbalanced power system, C.L. fortescue introduced method called symmetrical components in 1918 to solve such system using a balanced representation.

**4.4 PROTECTION SCHEME IN POWER SYSTEM**

**RELAY:**

A relay is an electrically operated switch. Many relays use an electromagnet to mechanically operate a switch, but other operating principles are also used, such as solid state relays. Relays are used where is necessary to control a circuit by a low power signal, or where several circuits must be controlled by one signal. The first relays were used in long distance telegraph circuits as amplifiers: they repeated the signal coming in from one circuit and re-transmitted it on another circuit. Relays were used extensively in telephone exchanges and early computers to perform logical operations.

A type of relay that can handle the high power required to directly control an electric motor or other loads is called a contractor. Solid state relays control power circuits with no moving parts, instead using a semiconductor device to perform switching. Relays with calibrated operating characteristics and sometimes multiple operating coils are used to protect electrical circuits from over load or faults; in modern electric power systems these functions are performed by digital instruments still called “protective relays”.

TYPES OF OVER CURRENT RELAY:

1. Instantaneous over current relay

2. Definite time over current relay

3. Inverse time over current relay

CHAPTER – 5

Test system

**Test system**

**5.1 Tested system in this project**

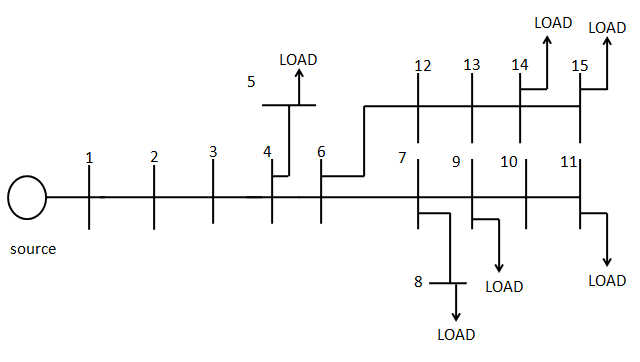
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Fig 5.1: Single line diagram of the real distribution system

Fig.5.1 represents the configuration of the distribution system at Tanta city as a part of the Egyptian West Delta distribution system. The studied distribution system consists of 15 nodes. The flat voltage for the systems is (11kV) at node 1. Node 1 is 66/11 transformer, other buses refers to possible loading point. The voltage at the first node on the feeder is (10.27 kV).

**5.2 Data for distribution system**

|  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| NODE  NUMBER | LINE | | | LENGTH  (KM) | LINE PARAMETERS | | | INDUCTANCE  (H/KM)\*e-3 | CAPACITANCE  (F/KM)\*e-9 |
| FROM | | TO | R  (Ω/KM) | X  (Ω/KM) | Y/2 |
| 2 | 1 | 2 | | 0.078 | 0.163 | 0.089 | 0.00007 | 0.28329 | 445.633 |
| 3 | 2 | 3 | | 0.85 | 0.266 | 0.095 | 0.00005 | 0.30239 | 318.309 |
| 4 | 3 | 4 | | 0.22 | 0.569 | 0.106 | 0.00004 | 0.3374 | 254.647 |
| 5 | 4 | 5 | | 0.05 | 0.569 | 0.106 | 0.00004 | 0.3374 | 254.647 |
| 6 | 5 | 6 | | 0.33 | 0.569 | 0.106 | 0.00004 | 0.3374 | 254.647 |
| 7 | 6 | 7 | | 0.2 | 0.569 | 0.106 | 0.00004 | 0.3374 | 254.647 |
| 8 | 7 | 8 | | 0.04 | 0.569 | 0.106 | 0.00004 | 0.3374 | 254.647 |
| 9 | 8 | 9 | | 0.65 | 0.269 | 0.095 | 0.00005 | 0.30239 | 318.309 |
| 10 | 9 | 10 | | 0.15 | 0.569 | 0.106 | 0.00004 | 0.3374 | 254.647 |
| 11 | 10 | 11 | | 0.1 | 1.113 | 0.117 | 0.00003 | 0.37242 | 190.985 |
| 12 | 11 | 12 | | 0.44 | 0.569 | 0.106 | 0.00004 | 0.3374 | 254.647 |
| 13 | 12 | 13 | | 0.15 | 0.266 | 0.095 | 0.00005 | 0.30239 | 318.309 |
| 14 | 13 | 14 | | 0.45 | 0.266 | 0.095 | 0.00005 | 0.30239 | 318.309 |
| 15 | 14 | 15 | | 0.2 | 0.266 | 0.095 | 0.00005 | 0.30239 | 318.309 |

Fig 5.2 Data for distribution system

# The simulation data considered has an ideal source with the following generation data as: RMS vault =10.27 kV (phase to phase), f=50 Hz (R & L series sources Rs=0.00893 Ω - Ls= 16.52e-5H).

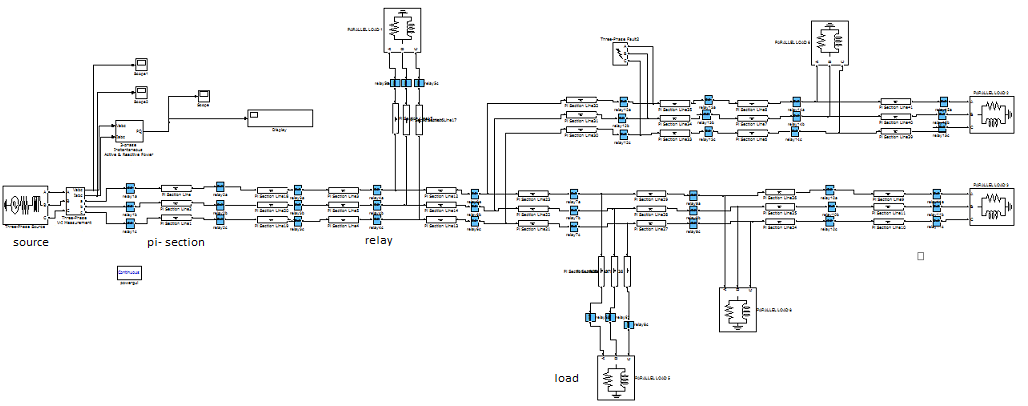
All the studied cases consider the load at distribution nodes as:

Load 1: 1.85 MW Load 2: 0.901 MW Load 3: 0.9 MW

Load 4: 0.857MW Load 5: 0.92 MW Load 6: 0.91 MW

The **DG** unit is inserted to the simulation model at the same voltage with R&L series parameters as RDG=0.08829 Ω & LDG = 15.92 mH.

**5.3 Simulink diagram for tested system**

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**Fig. 5.**3 Simulink diagram

**5.4 Effect of size of distribution generation**

The capacity of the distributed generator would also influence the protection scheme due to changes in fault current magnitudes. Hence, the performance of the proposed scheme has been tested by considering the multiple DG’s. Hence, the capacity of DGs has been varied by considering multiple DG’s.

The Fault Indices for various bus faults have been calculated. Faults have been simulated at all the buses varying the number of DGs from 0(without DG) to 3. The DGs are placed at 4th, 9th, 12th, buses varying the number of DGs of same capacity.

The Fault currents at each bus are sampled at a frequency of 1600 Hz. Fault Index have been calculated and compared with the same threshold value.

**5.5 Selection of threshold value**

An extensive study has been made by simulating faults at all the buses and calculating the fault index at all the buses for each fault. The same study has been repeated by introducing multiple DGs of same capacity at 4th, 9th, 12th bus.

In this study the buses are classified as *affected buses* (between source(s) and fault) and *Unaffected buses* (beyond the fault and source(s)). The fault index for both affected and unaffected buses form two regions i.e., Tripping region and blocking region. The range which separates these two regions is selected to fix the threshold value.

**5.6 Flow chart of this project**

Start

Start

Initialize moving window

With 16 samples

Calculate d1 coefficients of first level

decomposition using Haar Wavelets

Calculate the fault index

Fi = sum of abs( d1coefficients)

Move the window by one sample

Is

Fi >Threshold

Trip

Fig: 5.6 Flow chart

CHAPTER – 6

SIMULATION RESULTS

**6.1 Fault Index at different buses without DG**

**6.1.1 Fault Index at bus 4 in phase-a**

|  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- |
| Faulty buses | Without DG  \* (104) | DG at bus4  \*(104) | DG at bus9  \* (104) | DG at bus12  \* (103) | DG at bus4,9  \* (103) | DG at bus9,12  \* (103) | DG at bus4,12  \* (103) | DG at bus4,9,12  \* (103) |
| Bus 1 | 1.0018 | 1.0007 | 1.0001 | 1.0002 | 9.989 | 9.984 | 9.9897 | 9.9726 |
| Bus 2 | 1.0018 | 1.0006 | 1.0001 | 1.0001 | 9.989 | 9.984 | 9.9896 | 9.9727 |
| Bus 3 | 1.0017 | 1.0006 | 1 | 1.0001 | 9.9889 | 9.9842 | 9.9896 | 9.9734 |
| Bus 4 | 1.0017 | 1.0006 | 1 | 1.0001 | 9.9889 | 9.9842 | 9.9896 | 9.9732 |
| Bus 5 | 0.0019 | 0.0019 | 0.0019 | 0.0019 | 0.0188 | 0.0188 | 0.0188 | 0.0189 |
| Bus 6 | 0.0047 | 0.0047 | 0.0992 | 0.1013 | 0.9912 | 1.8717 | 0.0117 | 0.8701 |
| Bus 7 | 0.0028 | 0.0028 | 0.0982 | 0.0038 | 0.0807 | 0.9249 | 0.0384 | 0.9239 |
| Bus 8 | 0.0009 | 0.0009 | 0.0014 | 0.0012 | 0.0142 | 0.0169 | 0.0125 | 0.017 |
| Bus 9 | 0.0019 | 0.0019 | 0.0978 | 0.0026 | 0.0771 | 0.9241 | 0.026 | 0.9233 |
| Bus 10 | 0.0009 | 0.0009 | 0.0017 | 0.0012 | 0.0167 | 0.0192 | 0.0121 | 0.0192 |
| Bus 11 | 0.0009 | 0.0009 | 0.0017 | 0.0012 | 0.0167 | 0.0192 | 0.0121 | 0.0192 |
| Bus 12 | 0.0019 | 0.0019 | 0.0026 | 0.0999 | 0.0255 | 0.9466 | 0.9985 | 0.9457 |
| Bus 13 | 0.0038 | 0.0038 | 0.004 | 0.0044 | 0.0404 | 0.047 | 0.0444 | 0.0471 |
| Bus 14 | 0.0019 | 0.0019 | 0.0026 | 0.0034 | 0.0255 | 0.0396 | 0.0343 | 0.0396 |
| Bus 15 | 0.001 | 0.001 | 0.0013 | 0.0017 | 0.0127 | 0.0197 | 0.0171 | 0.0197 |

Table: 6.1.1 Fault Index Fi in bus 4 for phase-a

**6.1.2 Fault Index at bus 4 in phase-b**

|  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- |
| Faulty  buses | Without DG  \* (104) | DG at  Bus 4  \*(104) | DG at  Bus 9  \*(104) | DG at  Bus 12 \*(104) | DG at  Bus4,9  \*(104) | DG at  Bus9,12 \*(104) | DG at  Bus4,12 \*(104) | DG at  Bus 4,9,12 \*(104) |
| Bus 1 | 1.4589 | 1.458 | 1.4574 | 1.4575 | 1.4566 | 1.4563 | 1.4567 | 1.4556 |
| Bus 2 | 1.4544 | 1.4535 | 1.4529 | 1.453 | 1.4521 | 1.4518 | 1.4522 | 1.4511 |
| Bus 3 | 1.433 | 1.432 | 1.4315 | 1.4316 | 1.4307 | 1.4303 | 1.4308 | 1.4296 |
| Bus 4 | 1.4324 | 1.4314 | 1.4309 | 1.431 | 1.4301 | 1.4297 | 1.4302 | 1.429 |
| Bus 5 | 0.0023 | 0.0023 | 0.0023 | 0.0023 | 0.0023 | 0.0023 | 0.0023 | 0.0023 |
| Bus 6 | 0.0059 | 0.0059 | 0.0955 | 0.0968 | 0.0955 | 0.182 | 0.0967 | 0.182 |
| Bus 7 | 0.0037 | 0.0037 | 0.0938 | 0.0044 | 0.0937 | 0.0908 | 0.0044 | 0.0908 |
| Bus 8 | 0.0011 | 0.0011 | 0.0014 | 0.0013 | 0.0014 | 0.0016 | 0.0013 | 0.0016 |
| Bus 9 | 0.0026 | 0.0026 | 0.0931 | 0.0032 | 0.093 | 0.0903 | 0.0032 | 0.0903 |
| Bus 10 | 0.0011 | 0.0011 | 0.0016 | 0.0013 | 0.0016 | 0.0018 | 0.0013 | 0.0018 |
| Bus 11 | 0.0011 | 0.0011 | 0.0016 | 0.0013 | 0.0016 | 0.0018 | 0.0013 | 0.0018 |
| Bus 12 | 0.0022 | 0.0022 | 0.0027 | 0.094 | 0.0027 | 0.0013 | 0.0039 | 0.0912 |
| Bus 13 | 0.0022 | 0.0022 | 0.0027 | 0.0034 | 0.0027 | 0.0038 | 0.0034 | 0.0038 |
| Bus 14 | 0.0023 | 0.0023 | 0.0027 | 0.0034 | 0.0027 | 0.0038 | 0.0034 | 0.0038 |
| Bus 15 | 0.0011 | 0.0011 | 0.0014 | 0.0017 | 0.0014 | 0.0019 | 0.0017 | 0.0038 |

Table: 6.1.2 Fault Index Fi in bus 4 for phase-b

**6.1.3 Fault Index at bus 4 in phase-c**

|  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- |
| Faulty  buses | Without DG  \*(104) | DG at bus4  \*(104) | DG at bus9  \*(104) | DG at bus12  \*(104) | DG at bus4,9  \*(104) | DG at bus9,12  \*(104) | DG at bus4,12  \*(104) | DG at  bus4,9,12  \*(104) |
| Bus 1 | 1.324 | 1.3234 | 1.3232 | 1.3232 | 1.3227 | 1.3226 | 1.3227 | 1.3229 |
| Bus 2 | 1.3201 | 1.3195 | 1.3193 | 1.3193 | 1.3188 | 1.3186 | 1.3188 | 1.3189 |
| Bus 3 | 1.3291 | 1.3084 | 1.3081 | 1.3082 | 1.3076 | 1.3074 | 1.3077 | 1.3078 |
| Bus 4 | 1.3101 | 1.3094 | 1.3091 | 1.3092 | 1.3086 | 1.3085 | 1.3087 | 1.3088 |
| Bus 5 | 0.0004 | 0.0005 | 0.0005 | 0.0005 | 0.0005 | 0.0005 | 0.0005 | 0.0005 |
| Bus 6 | 0.0015 | 0.0016 | 0.0912 | 0.0923 | 0.0912 | 0.1807 | 0.0923 | 0.1806 |
| Bus 7 | 0.0011 | 0.0011 | 0.0912 | 0.0016 | 0.0913 | 0.0896 | 0.0016 | 0.0896 |
| Bus 8 | 0.0002 | 0.0002 | 0.0005 | 0.0004 | 0.0005 | 0.0006 | 0.0004 | 0.0007 |
| Bus 9 | 0.0009 | 0.0009 | 0.0916 | 0.0013 | 0.0916 | 0.09 | 0.0013 | 0.0899 |
| Bus 10 | 0.0002 | 0.0002 | 0.0007 | 0.0004 | 0.0007 | 0.0008 | 0.0004 | 0.0008 |
| Bus 11 | 0.0002 | 0.0002 | 0.0007 | 0.0004 | 0.0007 | 0.0008 | 0.0004 | 0.0008 |
| Bus 12 | 0.0005 | 0.0005 | 0.0008 | 0.093 | 0.0008 | 0.0913 | 0.0929 | 0.0913 |
| Bus 13 | 0.0005 | 0.0005 | 0.0008 | 0.0013 | 0.0008 | 0.0017 | 0.0013 | 0.0017 |
| Bus 14 | 0.0005 | 0.0005 | 0.0008 | 0.0013 | 0.0008 | 0.0017 | 0.0013 | 0.0017 |
| Bus 15 | 0.0002 | 0.0002 | 0.0004 | 0.0007 | 0.0004 | 0.0008 | 0.0007 | 0.0008 |

Table: 6.1.3 Fault Index Fi in bus 4 for phase-c

**6.1.4 Fault Index at bus 9 in phase-a**

|  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- |
| Faulty  buses | Without  DG  \*(104) | DG at bus 4 \*(104) | DG at bus 9  \*(103) | DG at bus12  \*(103) | DG at bus4,9  \*(104) | DG at bus 9,12  \*(103) | DG at bus 4,12  \*(103) | DG at  bus 4,9,12  \*(103) |
| Bus 1 | 4.815 | 4.6998 | 4.7994 | 5.7602 | 4.6844 | 4.684 | 4.6436 | 4.6282 |
| Bus 2 | 4.815 | 4.6998 | 4.7994 | 5.7602 | 4.6844 | 4.684 | 4.6436 | 4.6282 |
| Bus 3 | 4.8151 | 4.6998 | 4.7996 | 5.7602 | 4.6844 | 4.684 | 4.6436 | 4.6282 |
| Bus 4 | 4.8151 | 4.6998 | 4.7996 | 5.7602 | 4.6844 | 4.684 | 4.6436 | 4.6282 |
| Bus 5 | 0.0758 | 0.0785 | 0.0757 | 0.0676 | 0.0784 | 0.078 | 0.0807 | 0.0807 |
| Bus 6 | 4.7394 | 4.8789 | 4.7239 | 5.7046 | 4.8635 | 4.6182 | 4.743 | 4.7275 |
| Bus 7 | 4.6865 | 4.825 | 4.671 | 6.1239 | 4.8096 | 4.9257 | 5.0765 | 5.0617 |
| Bus 8 | 0.0195 | 0.0198 | 0.0195 | 6.1027 | 0.0198 | 0.0201 | 0.0204 | 0.0204 |
| Bus 9 | 4.667 | 4.8052 | 4.6516 | 0.0216 | 4.7898 | 4.9056 | 5.0562 | 5.0413 |
| Bus 10 | 0.0086 | 0.0086 | 0.0085 | 0.0104 | 0.0085 | 0.0085 | 0.0085 | 0.0085 |
| Bus 11 | 0.0086 | 0.0086 | 0.0085 | 0.0104 | 0.0085 | 0.0085 | 0.0085 | 0.0085 |
| Bus 12 | 0.0529 | 0.054 | 0.0529 | 0.8234 | 0.054 | 0.0492 | 0.6309 | 0.6295 |
| Bus 13 | 0.0646 | 0.0658 | 0.0645 | 0.0573 | 0.0657 | 0.0693 | 0.0704 | 0.0704 |
| Bus 14 | 0.053 | 0.0541 | 0.0529 | 0.0455 | 0.0541 | 0.0598 | 0.0613 | 0.0613 |
| Bus 15 | 0.0263 | 0.0269 | 0.0263 | 0.0226 | 0.0269 | 0.0297 | 0.0305 | 0.0305 |

Table: 6.1.4 Fault Index Fi in bus 9 for phase-a

**6.1.5 Fault Index at bus 9 in phase-b**

|  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- |
| Faulty  buses | Without  DG  \*(103) | DG at bus4  \*(103) | DG at bus9  \*(103) | DG at bus12  \*(103) | DG at bus4,9  \*(103) | DG at bus9,12  \*(103) | DG at bus4,12  \*(103) | DG at  bus4,9,12  \*(103) |
| Bus 1 | 6.9715 | 6.8864 | 6.9559 | 6.8883 | 6.8715 | 6.8745 | 6.7932 | 6.7803 |
| Bus 2 | 6.9715 | 6.8864 | 6.9559 | 6.8883 | 6.8715 | 6.8746 | 6.7932 | 6.7803 |
| Bus 3 | 6.9717 | 6.8866 | 6.9561 | 6.8885 | 6.8717 | 6.8747 | 6.7934 | 6.7805 |
| Bus 4 | 6.9717 | 6.8866 | 6.9562 | 6.8886 | 6.8717 | 6.8748 | 6.7934 | 6.7805 |
| Bus 5 | 0.0809 | 0.082 | 0.0809 | 0.0819 | 0.082 | 0.082 | 0.0831 | 0.0832 |
| Bus 6 | 6.8946 | 6.9987 | 6.879 | 6.8113 | 6.9841 | 6.7975 | 6.9187 | 6.906 |
| Bus 7 | 6.8401 | 6.9442 | 6.8245 | 7.0063 | 6.9295 | 6.993 | 7.1217 | 7.1094 |
| Bus 8 | 0.0203 | 0.0205 | 0.0203 | 0.0207 | 0.0205 | 0.0208 | 0.021 | 0.021 |
| Bus 9 | 6.8199 | 6.9239 | 6.8042 | 6.986 | 6.9092 | 6.9727 | 7.1012 | 7.0889 |
| Bus 10 | 0.0104 | 0.0104 | 0.0104 | 0.0104 | 0.0104 | 0.0104 | 0.0104 | 0.0105 |
| Bus 11 | 0.0104 | 0.0104 | 0.0104 | 0.0104 | 0.0104 | 0.0105 | 0.0104 | 0.0105 |
| Bus 12 | 0.056 | 0.0568 | 0.0561 | 0.6167 | 0.0568 | 0.0162 | 0.6055 | 0.6051 |
| Bus 13 | 0.0561 | 0.0568 | 0.0561 | 0.0587 | 0.0569 | 0.0588 | 0.0595 | 0.0596 |
| Bus 14 | 0.0562 | 0.0569 | 0.0562 | 0.0588 | 0.057 | 0.0589 | 0.0596 | 0.0597 |
| Bus 15 | 0.0279 | 0.0283 | 0.028 | 0.0292 | 0.0283 | 0.0293 | 0.0596 | 0.0297 |

Table: 6.1.5 Fault Index Fi in bus 9 for phase-b

**6.1.6 Fault Index at bus 9 in phase-c**

|  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- |
| Faulty  buses | Without DG  \*(104) | DG at bus4  \*(103) | DG at bus9  \*(103) | DG at bus12  \*(103) | DG at bus 4,9  \*(103) | DG at bus 9,12  \*(103) | DG at bus 4,12  \*(103) | DG at bus 4,9,12  \*(103) |
| Bus 1 | 6.1827 | 5.9781 | 6.1756 | 6.0051 | 5.9721 | 5.9999 | 5.8042 | 5.8069 |
| Bus 2 | 6.1828 | 5.9782 | 6.1757 | 6.0051 | 5.9721 | 6 | 5.8043 | 5.807 |
| Bus 3 | 6.1832 | 5.9786 | 6.1761 | 6.0055 | 5.9725 | 6.0004 | 5.8047 | 5.8072 |
| Bus 4 | 6.1832 | 5.9786 | 6.1761 | 6.0056 | 5.9726 | 6.0005 | 5.8047 | 5.8072 |
| Bus 5 | 0.0675 | 0.0696 | 0.0676 | 0.0694 | 0.0697 | 0.0694 | 0.0714 | 0.0715 |
| Bus 6 | 6.1158 | 6.3124 | 6.1086 | 5.9363 | 6.3059 | 5.9376 | 6.132 | 6.1322 |
| Bus 7 | 6.0746 | 6.2699 | 6.0673 | 6.4381 | 6.2633 | 6.4323 | 6.6286 | 6.6233 |
| Bus 8 | 0.0138 | 0.0141 | 0.0139 | 0.0144 | 0.0142 | 0.0145 | 0.0147 | 0.0148 |
| Bus 9 | 6.0625 | 6.2574 | 6.0577 | 6.4252 | 6.2524 | 6.4202 | 6.6153 | 6.6099 |
| Bus 10 | 0.0019 | 0.0019 | 0.002 | 0.002 | 0.002 | 0.0021 | 0.002 | 0.0021 |
| Bus 11 | 0.0019 | 0.0019 | 0.002 | 0.002 | 0.002 | 0.0021 | 0.002 | 0.0021 |
| Bus 12 | 0.0428 | 0.0438 | 0.0429 | 0.601 | 0.0439 | 0.0102 | 0.5929 | 0.5921 |
| Bus 13 | 0.0428 | 0.0438 | 0.0429 | 0.0466 | 0.0439 | 0.0467 | 0.0479 | 0.048 |
| Bus 14 | 0.0429 | 0.0439 | 0.043 | 0.0467 | 0.044 | 0.0468 | 0.048 | 0.0481 |
| Bus 15 | 0.0213 | 0.0218 | 0.0214 | 0.0233 | 0.0219 | 0.0233 | 0.0239 | 0.0239 |

Table: 6.1.6 Fault Index Fi in bus 9 for phase-c

**6.1.7 Fault Index at bus 12 in phase-a**

|  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- |
| Faulty  buses | Without  DG  \*(103) | DG at bus4  \*(103) | DG at bus9  \*(103) | DG at bus12  \*(103) | DG at bus4,9  \*(103) | DG at bus9,12  \*(103) | DG at bus4,12  \*(103) | DG at bus4,9,12  \*(103) |
| Bus 1 | 5.0964 | 5.0483 | 5.056 | 5.0824 | 5.0018 | 5.0419 | 5.0341 | 4.9877 |
| Bus 2 | 5.0964 | 5.0483 | 5.056 | 5.0824 | 5.0018 | 5.0419 | 5.0341 | 4.9877 |
| Bus 3 | 5.0965 | 5.0483 | 5.0559 | 5.0824 | 5.0018 | 5.0418 | 5.0341 | 4.9876 |
| Bus 4 | 5.0966 | 5.0483 | 5.0559 | 5.0823 | 5.0018 | 5.0418 | 5.0341 | 4.9877 |
| Bus 5 | 0.0737 | 5.187 | 0.0758 | 0.0737 | 0.0786 | 0.0758 | 0.0765 | 0.0786 |
| Bus 6 | 5.0336 | 0.0794 | 4.9933 | 5.02 | 5.0754 | 4.9793 | 5.1727 | 5.061 |
| Bus 7 | 0.0769 | 0.0246 | 0.6618 | 0.0768 | 0.6422 | 0.0604 | 0.0793 | 0.6408 |
| Bus 8 | 0.0238 | 0.0549 | 0.0262 | 0.0238 | 0.0269 | 0.0262 | 0.0245 | 0.0269 |
| Bus 9 | 0.0531 | 0.0239 | 0.6682 | 0.0531 | 0.0494 | 0.0262 | 0.0548 | 0.648 |
| Bus 10 | 0.0231 | 0.0239 | 0.027 | 0.0231 | 0.0277 | 0.027 | 0.0239 | 0.0277 |
| Bus 11 | 0.0232 | 0.0239 | 0.027 | 0.0231 | 0.0277 | 0.027 | 0.0239 | 0.0277 |
| Bus 12 | 4.9712 | 5.1118 | 5.2461 | 4.9577 | 5.4055 | 5.2319 | 5.0976 | 5.3992 |
| Bus 13 | 0.0371 | 0.037 | 0.037 | 0.0369 | 0.0369 | 0.0375 | 0.0369 | 0.0402 |
| Bus 14 | 0.0184 | 0.0184 | 0.0183 | 0.0183 | 0.0183 | 0.0183 | 0.0183 | 0.0196 |
| Bus 15 | 0.0091 | 0.0091 | 0.0091 | 0.0091 | 0.0091 | 0.0091 | 0.0091 | 0.0096 |

Table: 6.1.7 Fault Index Fi in bus 12 for phase-a

**6.1.8 Fault Index at bus 12 in phase-b**

|  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- |
| Faulty  Buses | Without  DG  \*(103) | DG at bus4  \*(103) | DG at bus9  \*(103) | DG at bus12  \*(103) | DG at bus4,9  \*(103) | DG at bus9,12  \*(103) | DG at bus4,12  \*(103) | DG at bus4,9,12  \*(103) |
| Bus 1 | 7.3967 | 6.3296 | 7.3265 | 7.3818 | 7.2327 | 7.3135 | 7.2981 | 7.2205 |
| Bus 2 | 7.3967 | 6.3296 | 7.3265 | 7.3818 | 7.2328 | 7.3135 | 7.2982 | 7.2206 |
| Bus 3 | 7.3969 | 6.33 | 7.3267 | 7.382 | 7.233 | 7.3137 | 7.2984 | 7.2207 |
| Bus 4 | 7.3968 | 6.3301 | 7.3268 | 7.382 | 7.233 | 7.3137 | 7.2984 | 7.2208 |
| Bus 5 | 0.0799 | 0.0685 | 0.0809 | 0.08 | 0.0821 | 0.0809 | 0.0811 | 0.0824 |
| Bus 6 | 7.3215 | 6.6972 | 7.2513 | 7.3066 | 7.3845 | 7.2382 | 7.4371 | 7.3726 |
| Bus 7 | 0.0854 | 0.0667 | 0.641 | 0.0854 | 0.6301 | 0.0406 | 0.0863 | 0.6289 |
| Bus 8 | 0.0261 | 0.019 | 0.027 | 0.0261 | 0.0274 | 0.027 | 0.0264 | 0.0275 |
| Bus 9 | 0.0595 | 0.0479 | 0.6421 | 0.0595 | 0.0317 | 0.0416 | 0.06 | 0.6313 |
| Bus 10 | 0.0253 | 0.0188 | 0.0269 | 0.0254 | 0.0272 | 0.0269 | 0.0257 | 0.0272 |
| Bus 11 | 0.0254 | 0.0189 | 0.0269 | 0.0254 | 0.0273 | 0.0269 | 0.0257 | 0.0273 |
| Bus12 | 7.2423 | 6.6306 | 7.4584 | 7.2274 | 7.5995 | 7.4458 | 7.358 | 7.5871 |
| Bus13 | 0.0222 | 0.0043 | 0.0223 | 0.0223 | 0.0223 | 0.023 | 0.0223 | 0.0311 |
| Bus14 | 0.0223 | 0.0044 | 0.0224 | 0.0225 | 0.0225 | 0.0226 | 0.0225 | 0.0241 |
| Bus 15 | 0.0112 | 0.0023 | 0.0112 | 0.0112 | 0.0112 | 0.0113 | 0.0112 | 0.0117 |

Table: 6.1.8 Fault Index Fi in bus 12 for phase-b

**6.1.9 Fault current at bus 12 in phase-c**

|  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- |
| Faulty  buses | Without  DG  \*(103) | DG at bus4  \*(103) | DG at bus9  \*(103) | DG at bus12  \*(103) | DG at bus4,9  \*(103) | DG at bus9,12  \*(103) | DG at bus4,12  \*(103) | DG at bus4,9,12  \*(103) |
| Bus 1 | 6.5347 | 6.3296 | 6.3757 | 6.5282 | 6.173 | 6.3712 | 6.3241 | 6.1765 |
| Bus 2 | 6.5347 | 6.3296 | 6.3757 | 6.5283 | 6.1731 | 6.3713 | 6.3242 | 6.1765 |
| Bus 3 | 6.5352 | 6.33 | 6.3762 | 6.5287 | 6.1735 | 6.3717 | 6.3246 | 6.1769 |
| Bus 4 | 6.5352 | 6.3301 | 6.3763 | 6.5288 | 6.1735 | 6.3718 | 6.3247 | 6.1768 |
| Bus 5 | 0.0664 | 0.0685 | 0.0681 | 0.0665 | 0.0702 | 0.0681 | 0.0686 | 0.0701 |
| Bus 6 | 6.469 | 6.6972 | 6.3083 | 6.4624 | 6.5353 | 6.3102 | 6.6914 | 6.5364 |
| Bus 7 | 0.0649 | 0.0667 | 0.6142 | 0.0651 | 0.6072 | 0.0153 | 0.0669 | 0.6083 |
| Bus 8 | 0.0184 | 0.019 | 0.0202 | 0.0184 | 0.0207 | 0.0202 | 0.019 | 0.0207 |
| Bus 9 | 0.0467 | 0.0479 | 0.631 | 0.0468 | 0.0238 | 0.0304 | 0.048 | 0.623 |
| Bus 10 | 0.0183 | 0.0188 | 0.0211 | 0.0468 | 0.0217 | 0.0212 | 0.0189 | 0.0218 |
| Bus 11 | 0.0183 | 0.0189 | 0.0212 | 0.0183 | 0.0217 | 0.0212 | 0.0189 | 0.0218 |
| Bus 12 | 6.4042 | 6.6306 | 6.8253 | 6.4078 | 7.0473 | 6.8286 | 6.6342 | 7.049 |
| Bus 13 | 0.0043 | 0.0043 | 0.0044 | 0.0045 | 0.0045 | 0.0054 | 0.0045 | 0.0135 |
| Bus 14 | 0.0044 | 0.0044 | 0.0045 | 0.0045 | 0.0045 | 0.0046 | 0.0046 | 0.0059 |
| Bus 15 | 0.0022 | 0.0023 | 0.0023 | 0.0023 | 0.0023 | 0.0024 | 0.0023 | 0.0027 |

Table: 6.1.9 Fault Index Fi in bus 12 for phase-c

**6.2 Threshold value for phase a, b, c**

|  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- |
|  | min ia | max ia | min ib | max ib | min ic | max ic |
| Fault at relay 2 | 62098 | 2152 | 74719 | 1724 | 74988 | 1695 |
| Fault at relay 3 | 13675 | 2688 | 19789 | 2659 | 18030 | 1759 |
| Fault at relay 4 | 9973.2 | 47 | 14290 | 1820 | 13074 | 930 |
| Fault at relay 5 | 9363.5 | 1708 | 13536 | 1679 | 12175 | 1673 |
| Fault at relay 6 | 6926.8 | 1065.3 | 10215 | 970 | 9012.3 | 947.9 |
| Fault at relay 7 | 5856.5 | 1083.2 | 8612.7 | 977.7 | 7456.4 | 942.9 |
| Fault at relay 8 | 5701.8 | 1038.7 | 8308.4 | 940.6 | 7188.1 | 908.8 |
| Fault at relay 9 | 4618.2 | 630.9 | 6780.3 | 616.7 | 5804.2 | 592.9 |
| Fault at relay 10 | 4230.2 | 582.4 | 6183.9 | 557.3 | 5225.9 | 543.6 |
| Fault at relay 11 | 3858.4 | 512.5 | 5565.7 | 495.7 | 4637.6 | 484.9 |
| Fault at relay 12 | 4957.7 | 668.2 | 7220.5 | 642.1 | 6173 | 614.2 |
| Fault at relay 13 | 3275.7 | 629.8 | 6846.6 | 600.9 | 5824.9 | 595.1 |
| Fault at relay 14 | 2862.9 | 536.2 | 5928.3 | 497.6 | 4979.2 | 506.4 |
| Fault at relay 15 | 2711.4 | 502.3 | 5597.1 | 493.5 | 4680.2 | 474.3 |
|  |  |  |  |  |  |  |
|  | 2711.4 | 2688 | 5565.7 | 2659 | 4637.6 | 1759 |

Table: 6.2 threshold values of phase a, b& c

Threshold value has been fixed at 2700 for phase-a

Threshold value has been fixed at 4600 for phase-c

Threshold value has been fixed at 5500 & above for phase-b

**6.3 Fault index of three phases at bus 4**

When the fault occurred at bus 4 the detail coefficients are taken for three phases. From the detail coefficient the absolute values of the detail coefficients are calculated. After calculating the absolute values then we calculated the fault index for three phases. The fault index is the sum of the absolute values of the detail coefficients in one half cycle i.e, 8 samples. This is shown in fig: 6.3 for all the phases. The threshold values are marked to differentiate faults in three phases. The variation of fault index when the DG capacity is changed by considering multiple DG’s for bus4 is shown in section 6.1. The simulation results prove that the proposed scheme has been effective in detecting the faults in the presence of DG as well as in the absence of DG i.e., with zero capacity.

Fig: 6.3 fault index for 3 phase fault at bus 4

**6.4 Fault index of three phases at bus 9**

When the fault occurred at bus 9 the detail coefficients are taken for three phases. From the detail coefficient the absolute values of the detail coefficients are calculated. After calculating the absolute values then we calculate the fault index for three phases. The fault index is the sum of the absolute values of the detail coefficients in one half cycle i.e, 8 samples. This is shown in fig: 6.3 for all the phases. The threshold values are marked to differentiate faults in three phases. The variation of fault index when the DG capacity is changed by considering multiple DG’s for bus9 is shown section 6.1. The simulation results prove that the proposed scheme has been effective in detecting the faults in the presence of DG as well as in the absence of DG i.e., with zero capacity

Fig6.4 fault index for three phase at bus 9

**6.5 Fault index of three phases at bus 12**

When the fault occurred at bus 12 the detail coefficients are taken for three phases at 12 bus. From the detail coefficient the absolute values of the detail coefficients are calculated. After calculating the absolute values then we calculate the fault index for three phases. The fault index is the sum of the absolute values of the detail coefficients in one half cycle i.e, 8 samples. This is shown in fig: 6.3 for all the phases. The threshold values are marked to differentiate faults in three phases.

The variation of fault index when the DG capacity is changed by considering multiple DG’s for bus12 is presented in tables shown section 6.1. The simulation results prove that the proposed scheme has been effective in detecting the faults in the presence of DG as well as in the absence of DG i.e., with zero capacity .

Fig: 6.5 fault index for three phase at bus 12

**6.6 FAULT INDEX FOR DIFFERENT DG’s AND PHASES**

**6.6.1 FAULT INDEX WITH DG AT BUS 4**

In this project we have considered multiple DG’s at buses 4, 9 and 12,faults are simulated at each bus. The fault index variation of phase -a at bus 4 is shown in the figure 6.6.1. The graphs are plotted for phase b and phase c in the figures 6.6.1.2, and fig.6.6.1.3

Fig: 6.6.1 fault index at bus 4 for phase a

Fig: 6.6.1.2 fault index at bus 4 for phase b

Fig: 6.6.1.3 fault index at bus 4 for phase c

**6.6.2 FAULT INDEX WITH DG AT BUS 9**

In this project we have considered multiple DG’s at buses 4, 9 and 12,faults are simulated at each bus. The fault index variation of phase -a at bus 9 is shown in the figure 6.6.2. The graphs are plotted for phase b and phase c in the figures 6.6.2.2, and fig.6.6.2.3

Fig. 6.6.2 fault index at bus9 for phase a

Fig. 6.6.2.2 fault index at bus9 for phase b

Fig. 6.6.2.3 fault index at bus9 for phase c

**6.6.3 FAULT INDEX WITH DG AT BUS 12**

In this project we have considered multiple DG’s at buses 4, 9 and 12,faults are simulated at each bus. The fault index variation of phase -a at bus 12 is shown in the figure 6.6.3. The graphs are plotted for phase b and phase c in the figures 6.6.3.2, and fig.6.6.3.3

Fig.6.6.3 fault index at bus12 for phase a

Fig.6.6.3.2 fault index at bus12 for phase b

Fig.6.6.3.3 fault index at bus12 for phase-c

CHAPTER-7

CONCLUSION

**Conclusion**

WT based approach of resolving the signals at multiple levels can be applied successfully for detection of faults in distribution networks with and without distributed generation effectively. Fault detection can be accomplished within half cycle using detail coefficients of currents. The proposed protection scheme is observed to be fast and reliable for multiple DG power system. The protection scheme has been proved to be successful in detecting the faults for various capacities of DG and also the faults in the phases can be differentiated using fault index and reliable threshold.

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