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J. Electrical Systems 18-1 (2022): 23-38

Regular paper

Wavelet-ANN Based Analysis of PV-IoT Integrated Two Area Power System Network Protection in presence of SVC

Journal of Electrical Systems

Power system network is one of the most widely used in engineering system in the field of electrical field for moving bulk amount of power from one location to the other several directions of the country over thousands of kilometres. Integration of power projects typically involves adding new energy sources like wind, solar generation units with shunt and series compensating devices to an existing power system network. It is essential to design new protection scheme due to changes in the topology and dynamic behaviour of the system. Now fast fault detection algorithmic approaches are necessary to integrate different types of generating sources and loads under smart environment. The protection scheme must provide physical monitoring as well as para-metrical with the help new technologies. Internet-of-things(IoT) is one of the source to monitor electrical systems under various environmental conditions of the system. Wavelet (WT) basically investigates the fault transient signals of different frequency and divides the waveform into different approximate and detailed coefficient values, which provides the important knowledge about the classification and location of fault. The detection of faulty-line and the location of fault by implementation wavelet detailed coefficients of Bior1.5 mother wavelet and for location of transmission line fault using Artificial neural network technique. This proposed method provide Condition monitoring Analysis of IoT based Wind-SVC Integrated Two Area Power System Network Protection scheme using artificial neural networks and wavelet approach under various types of faults.

Keywords: neural networks, Wavelet Transform,Solar-PV, SVC, Fault detection, Internet of things (IoT)

1. Introduction

The task of the power transmission system is to transfer electric power from generating stations to load distribution centres and then consumer premises through substations and other utilities. The electrical power system should serve all its customers and inter connect partners economically and reliably. Transmission lines are transfer bulk amount of power from one location to the other location of the country. The conventional solution approach can be described as upgrading system infrastructure by erecting new lines, substations with associated equipment. The high voltage power line carry large amount of power could extend several hundreds of kilometres. Since most of the lines are frequently overhead lines and are exposed in bad weather conditions, there are more chances damage due to outside objects, insulator damage and also storms will disturb the transmission system. It leads to give trouble to get continuous supply, which produces enormous changes in system operating condition. Abnormal conditions are detected and prevented by protective relaying scheme and it will operate automatic switching mechanism to clear the fault by isolating faulty equipment from the existing network. Distance protection [1] is characterised by the ratio of two input quantities respectively proportional to the voltage and current at particular relay point. The basic measurement of impedance in comparators circuit. Now a day these type of protection may not suitable due to large detection time as well as isolation

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of faulty element and also it has several drawbacks [2,3] like to unwanted operation during power swings and heavy loading conditions which may leads to tripping stream and spread blackouts. Hence, it was necessary to think about alternative protection instead of distance protection scheme. In [4], now digital communication based relays to designed for different operating condition of the system is proposed to detect the fault in the terminal and zones. For the benefit of the mechanical protection Internet-of-Things (IoT) has emerged as one of the upcoming technologies for a smart grid network. As the IoT connected power network enable to develop more prominent protection scheme not only electrical as well as mechanical challenges in the existing grid network such as in design, erection commissioning, operation and maintenance [4]. Cyber security triggers numerous problems in the system have been addressed and discussed in [5,6] about availability, integrity and confidentiality. Wired communication temporarily solve the problem but it gives problem due to interference communication channels. Few technologies related to broad band, GSM, GPRS Zigbee which cover up to the range of few kilometres due to the lack of data. The applicable fast and secure communication method is Optical fibre but is very expensive [9]. since these devices are online hence making the smart grid protect to significant attacks.

A micro-grid comprises of three main components which are micro- generators, distribution and different loads. The formation of micro-grid can be Single or multi terminal with 1φ/3φ system and it is connected to low or medium-voltage for distribution of electric power, and can operate under normal and island modes [10]. Micro-grid protection has complicated challenges in design of protection scheme and which can respond main and micro-grid faults. The level of protection is depending on fault current magnitudes in the system [11,12]. The protection scheme must face the problem comparing with existing power systems is that the fault current flow is unidirectional for radial system, but in the case of micro-grid the current flow is bidirectional flow [13]. A solar photo voltaic is frequently used energy source in power sector industry. The selection of protective element is complex due to coordination required between grid side over-current protection and distance protection at transmission line discussed in [14], but these type of systems can capable to suppress challenges of electrical protection system [15]. Considering the available information, a half cycle based moving window average technique for wind source integrated tapped transmission line [16]. Now a day, the system must capable to reduce transient oscillations due to frequently changing loads and protect the system from the faults. The past transmission system is unable to manage the control of load fluctuations and unwanted disturbances. The design of new method not only increase the cost as well as decrease in efficiency, but it also increases the complexity of the system. Therefore, attention is required for the stability and security of the utility grid as well as micro-grid. For the protection of existing system various approaches are investigated and found some of the alternative mechanisms are formulated such as reactive power compensation by installation of power electronics based devices to increase security of the power system. The proposed method requires faster response of power system parameters, reduce power loss and stability improvement. Based on research in advanced power electronics switching device and control technology improve the voltage control, reactive power flow, transient and steady state stability of the operation and control of transmission and distribution systems. The Static var compensator(SVC) is comprises of three components such as TCR, TSC and or FC named as thyristor-controlled-reactor, Thyristor-switched-capacitor and/or fixed-capacitor tuned to power filters combined with wind turbine at off-shore. The investigative results are compared and published on simulation platform in presence of FACTS devices and it is observed that problem is more severe when compared with SVC integrated system [17].

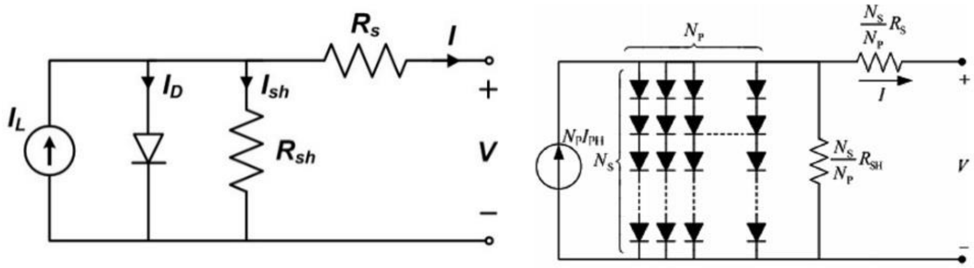
"Artificial-Neural-Network(ANN)" has been conveniently applied in various zone protection of different faults are analysed various artificial-intelligence(AI) methods discussed in [18]. An effective and efficient fault classification method has been presented in [19,20] with the analysis of currents and voltages of individual phases. The protection system can perform two major tasks mainly fault classification and forecast of fault location. Primary importance for discrimination and location of the faulted. This helps to safeguard the connected equipment as well as operating personnel and also immediate restriction of redundant power loss. Mostly unsymmetrical and symmetrical type of faults occur in transmission known as Single-line -ground(SLG), Double-line-ground(DLG), Double-line(DL) and Three-phase-ground (TPF) and also open-circuit(OC) faults. classification follows short circuit conditions of different phases: SLG-AG, BG and CG faults, DLG-ABG, BCG and CAG faults, DL-AB, BC and CA faults, LLL & LLLG faults. After getting faults in the system utmost care should be taken for restoration of system stability. The fault detection and location is major task to protect power system components for resuming normal power flow. A micro-grid protection based algorithm is described in [21] with the help of transient current wave form using wavelet detailed coefficients. The proposed research work concentrates Condition Monitoring Analysis of IoT based PV-SVC Integrated Two Area Power System Network Protection scheme using neuro-wavelet approach with wavelet based multi-Resolution-Analysis (MRA) is used with the calibration of coefficients of Bior-1.5mother-wavelet. Nowadays, the digital relays are working fast as well as accurate detection and isolation of the faulty element when compared to previous methods. The following sections discuss about the different effective method to analyses the faults of two area power system Network using IoT-Wavelet based Approach.

2. Mathematical Modelling of proposed system components

The proposed system comprises of Solar Photo voltaic elements with required essential components and reactive power shunt compensating device like Static-var-compensator(SVC). The mathematical modelling and analysis has been described as follows:

A. Solar photo-voltaic Modelling

The worldwide energy demand is increasing very rapidly because increase in industrialization and population, in response to this growth in requirement and demand, alternative technologies are incorporated in various countries for the purpose of diminishing the scarcity of electrical energy by incorporating renewable energy sources in the utility grid. The solar pv source is popular among the available non-conventional resources which provide electricity through solar energy conversion [14]. The PV modules which are used to generate electrical power through solar energy by grouping the solar cells in series and/or parallel as per the requirement of current and voltage. The equivalent circuit of PV module is represented in figure-1.The PV power plant consists of two important stages, first one comprises of DC-Dc boost converter, its basic function is to maximise the output power by utilise the maximum power point tracking (MPPT) algorithm and second one is voltage source converter(VSC),which provide DC-to-AC conversion and control[15].The converter contains power balance control with DC link voltage Proportional Integral (PI),Phase locked loop(PLL),direct and quadrature loop controllers



circit model of photo voltaic cell — circuit of solar photo voltaic model structure

Figure 1: General circuit of photo-voltaic module

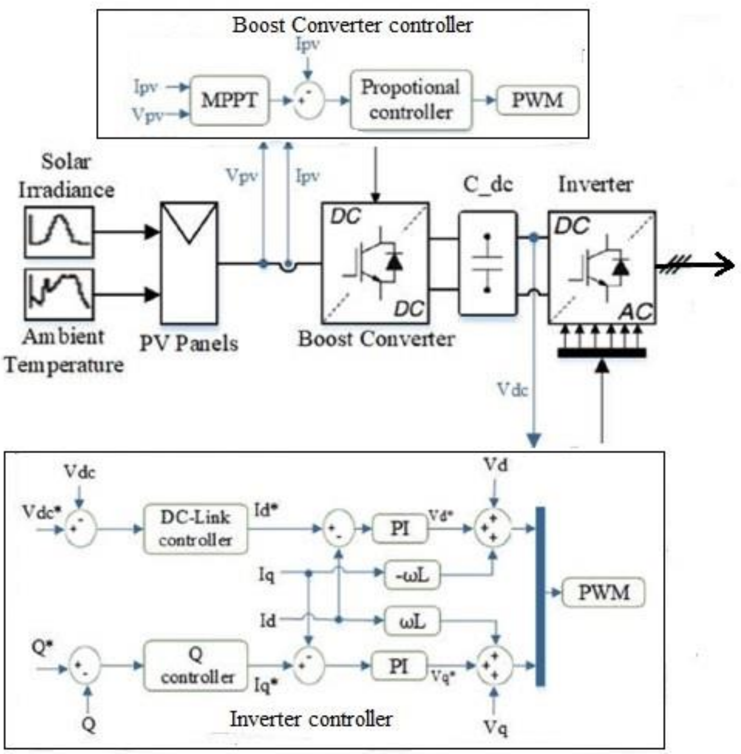


Figure 2: Modelling of solar photo voltaic control structure

The current-voltage characteristic can be represented by the equations as follows: PV module current equation can have written as

$$I_{ph} = [I_{sc} + K_i (T - 298)] * \frac{I_r}{100} \quad (1)$$

Reverse current saturation of module equation is

$$I_{rs} = \frac{I_{sc}}{\left[e^{\left(\frac{qV_{OC}}{N_S knT}\right)}\right]} \quad (2)$$

where VOC known as open circuit voltage in volts, N_s is no. of cells connected in series, k-Boltzmann's constant

Where Photon current I_{ph}, short circuit current I_{sc}, operating temperature T. Module saturation current with varying temperature can be calculated using equation

$$I_0 = I_{rs}\left[\frac{T}{T_r}\right]^3 e^{\left[\frac{q*E_{g0}}{nk}\left(\frac{1}{T}-\frac{1}{T_r}\right)\right]} \quad (3)$$

The output current of PV module is

$$I = N_p * I_{ph} - N_p * I_0\left[e^{\left(\frac{\frac{V}{N_s}+I*\frac{R_s}{N_p}}{n*V_T}\right)} - 1\right] - I_{sh} \quad (4)$$

where Np is no.of PV modules are connected in parallel, Rsh and Rs is known as shunt and series resistances measured in ohm

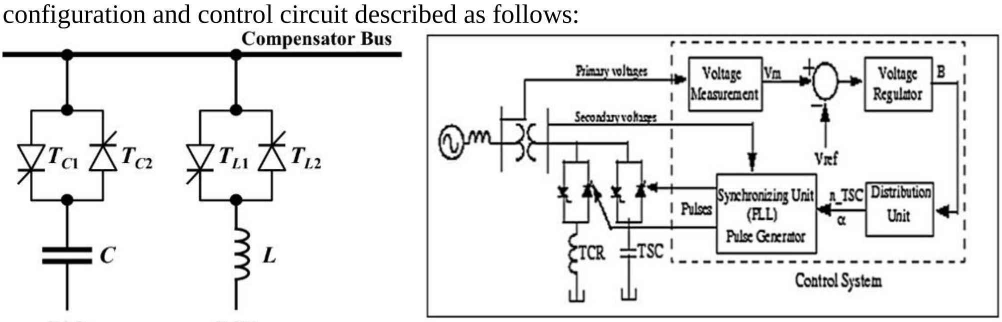
$$v_t = \frac{k*T}{q} \quad (5)$$

$$I_{sh} = \frac{V*\frac{N_p}{N_s}+I*R_s}{R_{sh}} \quad (6)$$

B. Static Var Compensator

The power electronics based shunt compensating device known as Static-VAR-compensators (SVC), which generates/absorbs reactive power and it control specific parameters of electric power network. It overcome the limitations of mechanical switching shunt capacitors or reactors. These are including fast switching, proper regulation of voltage and current. The basic components such as reactors and capacitor banks are connected in series with bidirectional thyristors. Static var compensators are capable to control individual current and voltages of individual phases in which they are connected. SVC provides an excellent control over the reactive power through dynamic voltage control by thyristor switching mechanism, which incorporate faster control bus voltage and compared with mechanical switched conventional devices.

The general configuration of SVC using TSC and TCR scheme with back-to-back connected thyrisor switches. The idea behind this is to keep transmission line voltage stable by introducing capacitance/inductance in the circuit. The reactive power compensator is line voltage keep stable by injecting reactive power through capacitance or Inductance depending on automatic voltage [22]. So, controlling signal generated by thyristor values have to be changed with automatic-voltage-controller signal. Figure 3 illustrated that SVC configuration and control circuit described as follows:



(a) SVC Configuration

(b) SVC Control circuit

Figure 3: SVC configuration and control circuit

The current magnitude can be continuously changed by delay angle (α = 0) at maximum and (α = 90) at zero, depending on the supply frequency in the reactor controlled by firing angle α in the thyristor conduction. The generator current depends on rotor angle δ, internal voltage v, the angular frequency ω and time t. The amplitude of current can have expressed as:

$$I_L(\alpha) = \frac{V}{\pi\omega}(2\pi - 2\alpha + 2\sin 2\delta) \quad (7)$$

The amplitude $I_L(\alpha)$ of the reactor fundamental current can be expressed as a an equation with α,amplitude of voltage applied(V) and impedance(L) of the thyristor controlled reactor.

The amplitude of applied voltage is maintained normally with reference to voltage V_{ref} through closed-loop control at load varying conditions. The system requires compensation at particular variation in magnitude of terminal voltage at different time quantum. The revised signal VR acquired from the supplementary inputs in order to obtain the desired effective reference signal.

$$B_{STC} = -\frac{1}{X_C X_L}\left(X_L - \frac{X_C}{\pi}\left[2(\pi - \alpha) + 2\,Sin(2\alpha)\right]\right) \quad (8)$$

$$i(\omega t) = V\frac{n^2}{n^2 - 1}\,\omega C\cos(\omega t) \quad (9)$$

A Thyristor switched capacitor scheme contains total capacitor bank is split in to separated size units, each can

be operated by using thyristor switches using bidirectional thyristors,which are connected in series with line.

So, its current varying from 0 to Imax. The following expressions illustrates the capacitor current:

$$n = \frac{1}{\sqrt{\omega^2 LC}} = \sqrt{\frac{X_C}{X_L}}$$

The thyristor voltage can be expressed when the thyristor valve is closed is given by:

V = V sin ωt

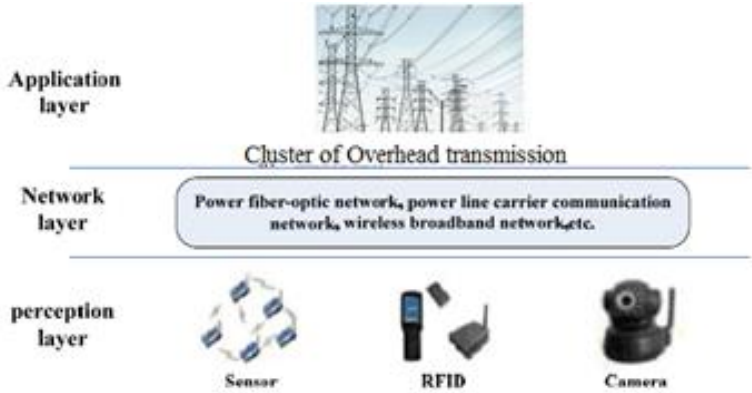
The compensating dynamic reactance of both TCS and TCR/FC are given by

$$X_{SVC} = j\omega L - \frac{j}{\omega C} \quad (10)$$

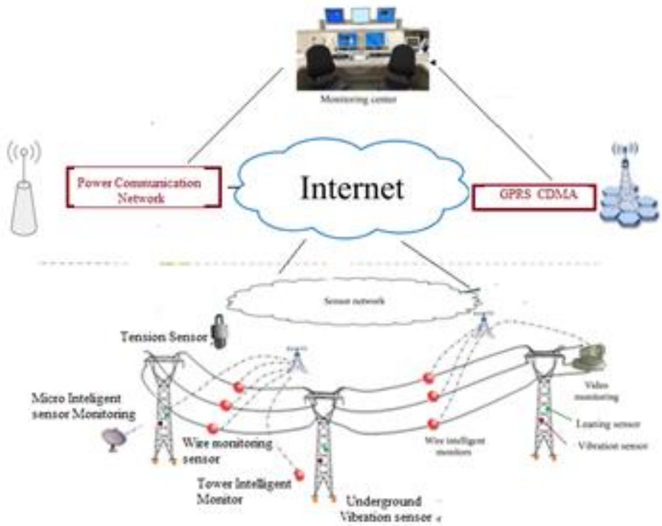
3. IoT Based Power system network protection scheme

The protection of transmission line using Internet of Things (IoT)formation contains 3-layers structure such as perception, network and application.

The perception layer can gather required information through sensors, RFID and camera for monitoring the electrical devices which are required to send information to network layer for the protection of power transmission network [22]. The network layer includes fiber-optic communication channels for transmitting date from one end to other end; power line carrier communication is required for transmitting electrical data and wireless networks for remote data collection. Application layer collect the information from various available sources and then make the protection scheme becomes real time system. IoT perform processing, integration and analysis of data, thus intelligent control services and decision making such that the protection scheme is improved.



(a) IoT Applications in Power system protection



(b) IoT aided protection of transmission system

Figure 4: IoT based power system network protection

This Iot system contains various sensors are generating premature warnings to the watching centres about physical and mechanical conditions of tower as well as conductor and also threats regarding of high voltage towers. The vibration sensors monitors underground vibrations discussed in[23]. IoT based transmission system protection incorporates mechanical and electrical safety of power lines from the problems of natural disasters, unsophisticated threats to construction, natural disaster and growing trees. The basic IoT based Power system network protection is described in fig.4.

4. ANN-Wavelet Analysis in power system protection

The mathematical modelling and analysis has been described as follows: Wavelet transform (WT) is popular tool for research to detect transient faults by analysing various types of signals and separate approximate and detailed coefficients using basic Bior1.5 mother wavelet, which gives tremendous information regarding fault classification and location[24].A power system with micro grid protection algorithm is described in [25] Multi-resolution- Analysis (MRA) through transient current signals with mother wavelets of faulty signals.

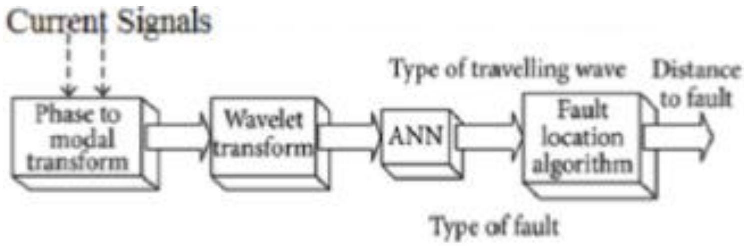


Figure 5: simplified diagram of Neuro-wavelet based Protection scheme

Artificial Neural Network(ANN) is one of the notified intelligence method to describe the investigation of power system problems. The operating conditions both internal faults and external disturbances are calibrated using training patterns of ANN test data. The ANN is fed either with wavelet detailed coefficients of the input signals extracted using certain measuring devices.

The samples of the signals are fed to the ANN and it encodes distance to fault. The output will alert trip signal to operate relay based on type of fault, direction of fault, etc. The operational procedure explains neural network and wavelet based Protection scheme is represented in figure.5

5. System Study and methodology

The proposed system comprises of Solar Photo voltaic elements with required essential components and reactive power shunt compensating device like Static-var-compensator(SVC).

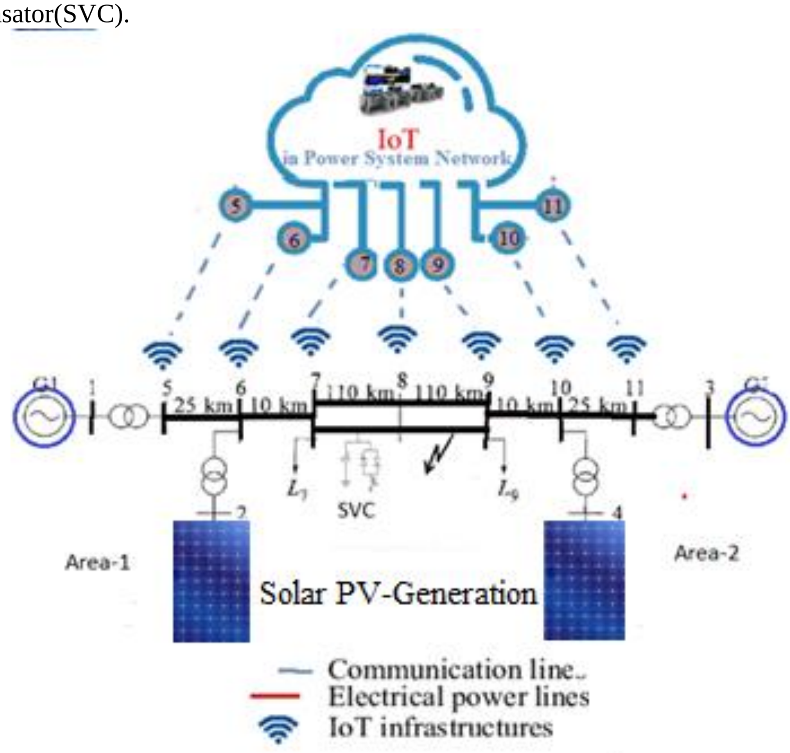


Figure 6: Proposed two area power network test system.

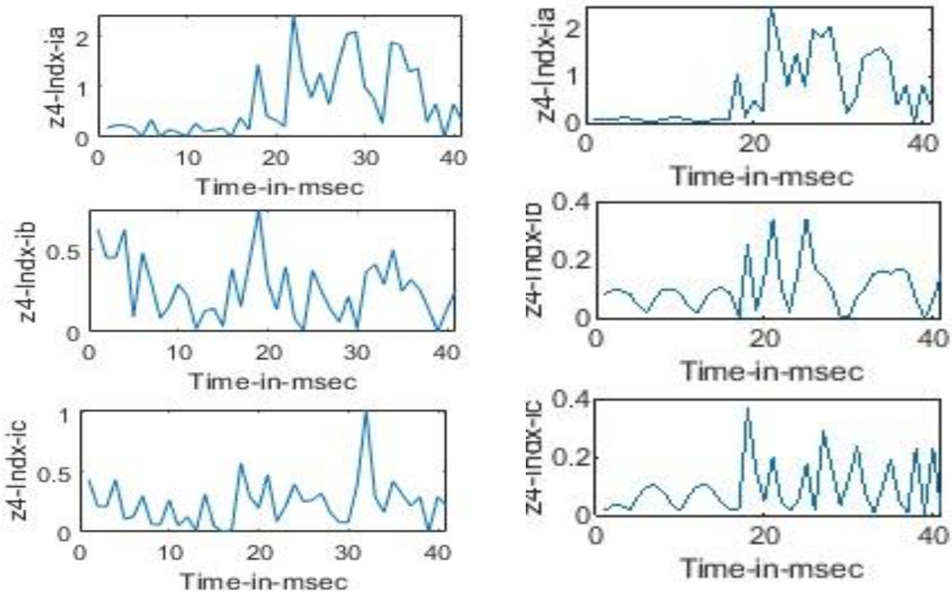
Table-1 technical parameters.

Terminal 1 & 3	Utility Grid ,230KV	Area-1		Area-2	
Terminal 3 & 4	Solar-PV Energy source, 10 MWP	Line section	Distance	Line section	Distance
Line parameters	R=0.0127Ω/Km, R0 = 0.386Ω/Km	Z1:B-5 &B- 6	25Km	Z1:B-10&B-11	25Km
	L=0.9337mH/Km, L0=4.126 mH/Km	Z2:B-6 &B-7	10 Km	Z1:B-9&B-10	10 Km
	C=12.74 nF/km, C0 = 7.751 nF/Km	Z3:B-7 &B- 8	110Km	Z1:B-8&B-9	110Km

The test system is a 230kV transmission system included 2-utility grids and 2-wind energy sources each 100 MW with Static Var controller(SVC) with different distances zones as illustrated in figure-6 and system technical parameters are represented in Table-1. The system total transmission line length is 300km and is divided into six Zones. The proposed system is calibrated of each zone under ten cases of faults with various distances in steps of 10.

6. Simulation results

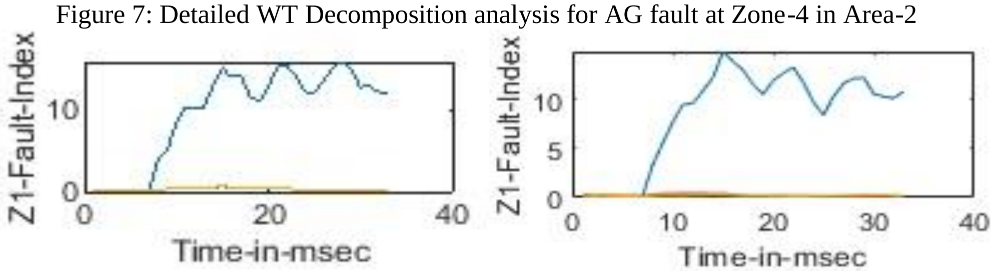
The fault cases are considered every zone of ten different types of faults. There are three main cases to study:
1) Type of fault-SG, SLG, DLG, TLG faults.
2) Total transmission line distance (from 0km to 290Km) divided in to 6 Zones and are divided in to Two areas.
The details about area-1 \& Area-2 as described in Table-I:
3) Fault Inception angles (from 0^0 to 180^0 in increments of 15 degrees
The Proposed work comprises detection\& discrimination and location of fault in various zones by utilisation of sum-of-the-Detailed coefficients of current signal of the system with and without shunt compensating device. i.e with and without SVC. The detection of fault is observed with the analysis of Z_x -fault-index values, where x indicates 1 to 6 zones. It is observed that Z4-fault-Index values are higher than other fault index values with SVC and without compensating SVC of FACTS Control device then the fault is identified as single-line-to- ground fault at Phase-A to ground illustrated in figure-7.The system network is calibrated at various distances and fault inception angle and it is found that faulty phase coefficients are above threshold value, which is in between least value of highest value of the faulty phase and highest value of healthy phase index value. The analysis of faulty phase in Area-1 is identified by the analysis from figure-8 to Figure-11 at different Zones at various types of faults and also The analysis of faulty phase in Area-1 is identified by the analysis from figure-12 to Figure-14 at different Zones at various types of faults with and without compensating device using the sum-of-detailed coefficients.



(a) PV energy source integrated system

(b) SVC-PV energy source integrated system.

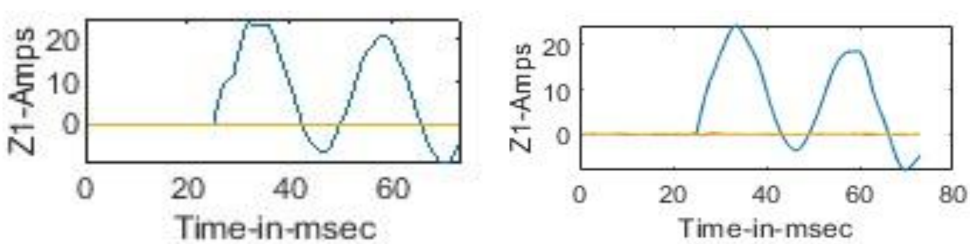
Figure 7: Detailed WT Decomposition analysis for AG fault at Zone-4 in Area-2



(a) PV energy source integrated system

(b) SVC-PV energy source integrated system

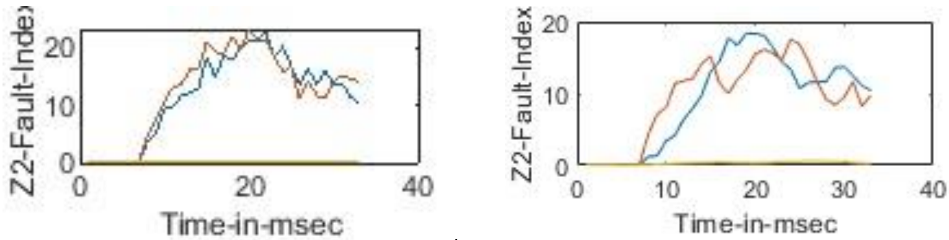
Figure 8: Fault analysis waveform of Zone-1in Area-1 of SVC-Solar Photo-voltaic energy source integrated system at AG Fault.



(a) PV energy source integrated system

(b) SVC-PV energy source integrated system

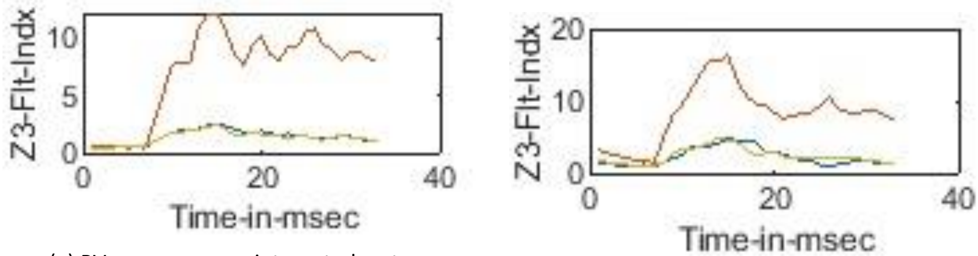
Figure 9: waveform of Zone-1 in area-1 of PV-SVC integrated system current signal at AG Fault



(a) PV energy source integrated system

(b) SVC-PV energy source integrated system.

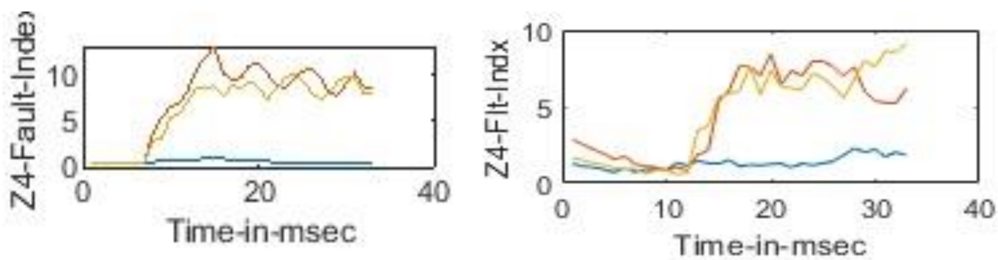
Figure 10: Fault analysis waveform of Zone-2 in Area-1 of PV-SVC integrated system at ABG Fault.



(a) PV energy source integrated system

(b) SVC-PV energy source integrated system

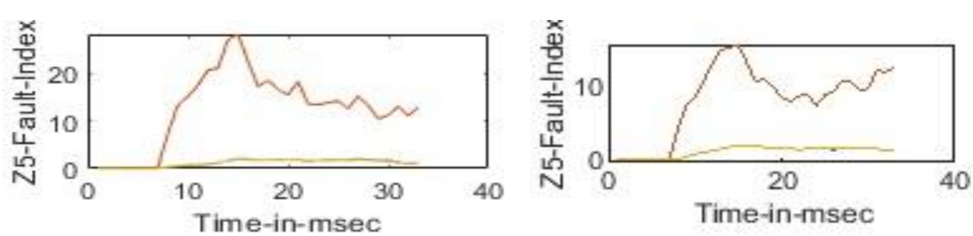
Figure 11: Fault analysis waveform of Zone-3 in Area-1 of PV-SVC integrated system at BG Fault.



(a) PV energy source integrated system

(b) SVC-PV energy source integrated system.

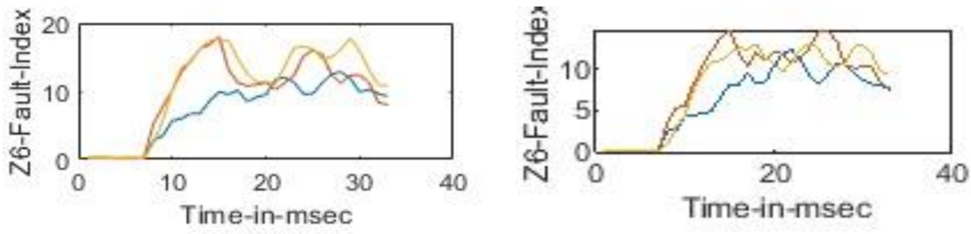
Figure 12: Fault analysis waveform of Zone-4 in Area-2 of PV-SVC integrated system at BCG Fault.



(a) PV energy source integrated system

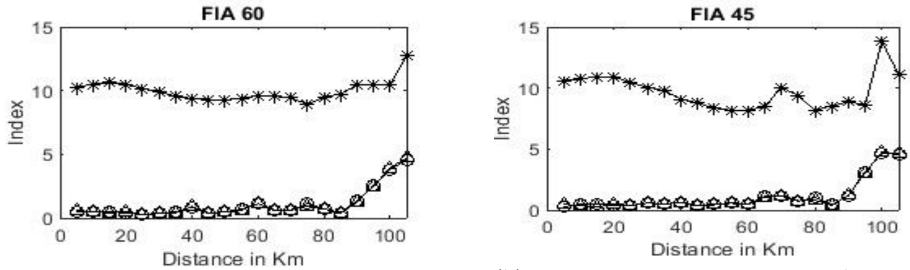
(b) SVC-PV energy source integrated system.

Figure 13: Fault analysis waveform of Zone-5 in Area-2 of PV-SVC integrated system at BCG Fault.



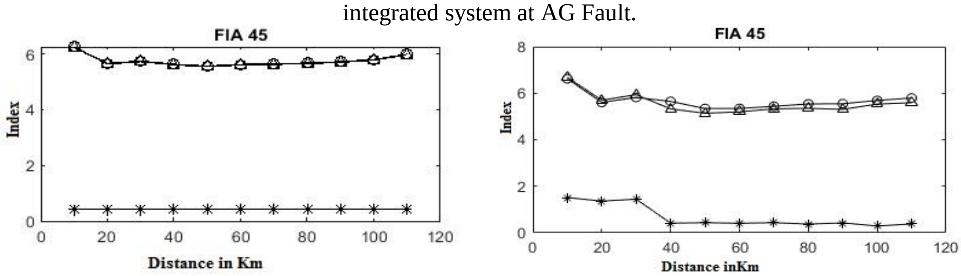
(a) PV energy source integrated system (b) SVC-PV energy source integrated system.

Figure 14: Fault analysis waveform of Zone-6 in Area-2 of PV-SVC integrated system at BCG Fault.



(a) PV energy source integrated system (b) SVC-PV energy source integrated system.

Figure 15: Analysis of fault at different distances in Zone-3 of area-1 of Photo-voltaic energy source integrated system at AG Fault.



(a) PV energy source integrated system (b) SVC-PV energy source integrated system.

Figure 16: Analysis of fault at different distances in Zone-4 of area-1 of Photo-voltaic energy source integrated system at AG Fault.

Table 2: Zone3-index: Analysis of fault at different distances in Zone-3 of area-1 of Solar-PV energy source with and without SVC integrated system at BG Fault

		Phase-A : Fault Inception Angle in Degrees PV						Phase-A : Fault Inception Angle in Degrees PV-SVC					
Distance		0	15	30	45	60	75	0	15	30	45	60	75
	10	0.948	0.832	0.907	0.816	0.781	0.696	1.537	1.521	1.531	1.373	1.235	1.072
	20	0.614	0.621	0.791	0.767	0.706	0.572	1.479	1.481	1.318	1.059	0.914	0.795
	30	0.501	0.558	0.627	0.695	0.605	0.543	0.832	0.792	0.699	0.832	0.856	0.798
	40	0.437	0.537	0.555	0.638	0.592	0.508	0.955	0.964	0.970	1.016	0.890	0.648
	50	0.751	0.824	0.761	0.744	0.534	0.629	0.771	0.667	0.749	0.674	0.674	0.596
	60	0.454	0.552	0.650	0.639	0.625	0.639	0.567	0.429	0.452	0.452	0.551	0.506
	70	0.639	0.648	0.759	0.715	0.656	0.514	1.185	1.003	1.065	0.918	0.824	0.706

	80	0.556	0.351	0.222	0.243	0.306	0.259	1.459	1.211	0.893	0.627	0.546	0.403
	90	0.429	0.324	0.289	0.270	0.257	0.279	0.981	0.881	0.937	1.007	0.773	0.763
	100	1.315	1.602	1.637	1.379	1.145	1.064	2.133	2.052	1.796	1.746	1.825	1.904

		Phase-B : Fault Inception Angle in Degrees PV						Phase-B : Fault Inception Angle in Degrees PV-SVC					
Distance		0	15	30	45	60	75	0	15	30	45	60	75
	10	10.32	10.77	9.428	8.319	8.064	9.172	9.411	9.656	9.021	7.630	7.915	8.683
	20	9.522	9.879	8.860	7.635	7.184	8.359	8.575	8.746	8.369	6.897	6.861	7.922
	30	9.281	9.371	8.734	7.280	7.101	7.938	8.344	8.321	8.069	6.710	6.417	7.404
	40	8.907	8.809	8.438	6.938	6.674	7.685	7.892	7.954	7.527	6.566	6.023	7.171
	50	8.918	8.722	8.623	6.883	6.601	7.529	7.815	8.173	7.500	6.558	6.209	7.065
	60	8.669	8.611	8.159	6.975	6.707	7.410	7.802	8.150	7.403	6.500	6.296	6.950
	70	7.725	8.127	7.156	6.361	6.039	6.870	7.032	7.266	6.819	5.605	5.667	6.573
	80	8.425	9.122	8.361	7.232	6.472	7.477	8.052	8.677	8.439	7.168	6.503	7.446
	90	9.374	8.978	8.629	7.032	6.314	7.202	9.276	9.239	8.168	7.202	6.614	7.019
	100	6.898	6.933	5.801	5.627	5.363	6.140	5.358	5.112	5.225	5.027	4.757	4.908

		Phase-C: Fault Inception Angle in Degrees PV						Phase-C: Fault Inception Angle in Degrees V-SVC					
Distance		0	15	30	45	60	75	0	15	30	45	60	75
	10	0.633	0.693	0.703	0.600	0.522	0.618	1.880	1.577	1.497	1.586	1.272	1.063
	20	0.647	0.497	0.480	0.555	0.562	0.665	1.352	1.033	0.992	1.082	0.982	1.002
	30	0.695	0.577	0.540	0.567	0.519	0.569	0.674	0.473	0.463	0.421	0.598	0.783
	40	0.550	0.468	0.514	0.539	0.595	0.643	1.451	1.338	1.189	0.982	0.835	0.827
	50	0.939	0.871	0.722	0.617	0.679	0.550	0.762	0.794	0.839	0.972	0.942	0.780
	60	0.630	0.552	0.518	0.564	0.598	0.549	1.289	1.193	1.041	0.905	0.784	0.561
	70	0.690	0.577	0.590	0.716	0.738	0.897	0.941	0.938	1.018	0.961	0.720	0.978
	80	0.959	0.633	0.687	0.795	0.767	0.781	0.920	0.997	0.882	0.954	0.943	0.816
	90	0.684	0.678	0.744	0.786	0.846	0.884	1.458	1.440	1.036	1.344	1.265	1.172
	100	1.465	1.593	1.441	1.312	1.366	1.588	1.971	2.242	2.155	1.877	1.766	2.057

The Zone current signal has sampling rate 264 kHz of Z1 to Z6 during the fault to analyse the data after selecting suitable wavelet. The analysis of fault at different distances in Zone-3 and Zone-4 are shown in figure-15 and figure-16.
According to the IEEE Definition.

$$Error = \frac{\text{Actual line length} - \text{Calculated line length}}{\text{Total Line Length}} * 100$$

The Simplified block diagram of wavelet transforms based fault location method using ANN is presented in figure3.
The neural network based location technique has tested under different types of faults at various distance are considered and found suitable for the proposed system and presented in Table:3 and 4 for Zone-3 and zone-4.

Table-3 : location of fault and error calculation based on Neural Network algorithm at Zone-3.

	Type of Fault							
	LG		**LLG**		**LL**		**LLLG**	
AD	CD	%E	CD	%E	CD	%E	CD	%E
20	20.04	-0.04	19.00	0.90	20.57	-0.52	19.38	0.55
30	30.55	-0.50	29.42	0.52	29.78	0.19	29.81	0.17
40	40.11	-0.10	42.47	-2.24	40.33	-0.30	43.02	-2.74
50	50.44	-0.40	51.40	-1.27	50.58	-0.52	49.78	0.19
60	59.01	0.89	61.52	-1.38	59.49	0.45	62.64	-2.40
70	72.13	-1.93	69.25	0.67	69.93	0.05	69.02	0.88
80	79.62	0.34	79.25	0.68	77.07	2.66	80.43	-0.39
90	89.39	0.55	91.53	1.38	89.97	0.02	91.86	-1.69
100	99.68	0.28	99.65	0.31	100.2	-0.21	100.0	-0.03

AD : Actual distance CD : Calculated Distance E : Error

Table 4 : location of fault and error calculation based on Neural Network algorithm at Zone-4

	Type of Fault							
	LG		**LLG**		**LL**		**LLLG**	
AD	CD	%E	CD	%E	CD	%E	CD	%E
20	18.62	1.25	20.07	-0.06	20.27	-0.24	19.78	0.20
30	31.20	-1.09	30.11	-0.10	30.49	-0.44	31.05	-0.95
40	41.63	-1.48	43.78	-3.43	40.16	-0.14	39.13	0.79
50	48.69	1.19	48.47	1.39	49.75	0.22	50.56	-0.50
60	63.49	-3.17	59.01	0.90	58.77	1.11	58.43	1.42
70	66.63	3.06	69.35	0.59	70.38	-0.34	70.39	-0.35
80	80.78	-0.70	82.14	-1.94	80.75	-0.68	79.54	0.41
90	89.79	0.19	88.44	1.41	91.65	-1.50	92.55	-2.31
100	99.43	0.51	98.43	1.42	101.16	-1.05	103.14	-2.85

AD : Actual distance CD : Calculated Distance E : Error

The proposed algorithm classifies faults with 100% accuracy and location of faults are found least error in all case studies,

The results of fault location under bior1.5 mother wavelet. For system study, total 10 types of faults in each Zone-4 and Zone-4 with 55 faulty points were considered as training patterns of NN and 9 points was considered for testing for 110km long transmission line as illustrated in table-5.

7. Conclusions

This paper proposes monitoring of Transmission system with the assistance of IoT and its applications, so that it can provide strong real protection scheme. IoT can solve real problems mechanical and physical problems with effective manner and also promoting the development of new protection algorithms. WT is one of the research tool to analyses the faults in transient signals at different frequencies by decomposing the waveform into coefficients of bior1.5 mother wavelet, which presents more prominent information regarding the class of fault and location in existing system by time and frequency domain. The Proposed algorithm has been tested for the detection and location of faults under various types of faults at different fault inception angles using wavelet multi resolution analysis with bios1.5 mother wavelets detailed coefficients with the help of IOT Application.

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