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Substation Monitoring System (SMS) For Remote Power Quality Monitoring and Analysis of Power Distribution Network using Object Oriented Web Enabled Method

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ABSTRACT

Power Quality issues are attempting a great importance as system approach rather than an individual problem. Based on supervision, control and performance of modern power system makes Power Quality monitoring a common practice for utilities. This paper presents an Object Oriented Web Enabled (OOWE) approach for remote Power Quality monitoring and analysis with harmonic considerations. The real time monitoring and analysis of power systems parameters is inherently complex due to large data handling process. Object Oriented Web Enabled approach has been used as computational tool which performs monitoring and analysis in substation related to Power Quality. To create user friendly environment, a GUI is created through Object Oriented Web Enabled method. An innovative approach in electrical field in terms of substation monitoring is used to transmit the data from remote station to the central server and authority sharing has been developed as per the process thereby improves Power Quality. Also analysis of Power Quality Indices, Power Quality Distortion Index (DI) and its formulation as a Power Quality parameter has been done for Indian distribution network for various categories of non-linear consumers.

Keywords: Distribution network, Harmonics, Lightning Arrestor(LA), Penalty Factor, Power Quality, Substation Monitoring System (SMS),Object Oriented Web Enabled (OOWE) method, Total Harmonic Distortion (THD)

1. INTRODUCTION

Power Quality is of ever growing concern to utilities and customers. The gradual rise in awareness of effect of Power Quality disturbances on substation equipments has led to many utilities, taking much pro-active approach towards the measurement of Power Quality levels on their networks. The problem associated with high harmonic content in the power system not only results in poor quality of supply but also the operation of the system will get affected. [3].In this paper Power Quality monitoring and its analysis is proposed through Substation Monitoring System (SMS) with Object Oriented Web Enabled(OOWE) method which comprises two main applications, Sub-Station client application and Substation Server Application. This Application will show all the sub-station along with the Report includes the Power Quality Parameters, Power Quality Indices, and Power Quality Distortion Index (DI) which gives the contribution of total distortion of each load of the power system.

1.2. Effect of Harmonics on substation Equipments

Electric power in distribution network is supplied at a constant system frequency and at specified voltage magnitudes. In realistic power system, however frequency and voltages are deviated from their designated values. The deviation from perfect sinusoidal waveform is generally term as harmonics. Saturable devices

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and power electronic devices are two general categories of harmonic sources. Saturable devices produce harmonics due to iron saturation as in the case of rotating machines, transformer and fluorescent lighting with magnetic ballast. Power electronic loads draw power only during portions of the applied voltage waveform. Thus current drawn by the load is no longer sinusoidal .This non-sinusoidal current can interact with the system impedance to give rise to voltage distortion and in some cases resonance. Today harmonics included by nonlinear power electronic loads present inefficient operations of local and global power supply system. Harmonics in power system deteriorate the quality of electric supply and can result in number of effects on power system equipments .These effects are listed below,

- Excessive losses and heating in major electrical equipments
- Degraded meter accuracy.
- A solid state device malfunctions.

Survey for the measurement of Power Quality has been done at different substations feeding power to various categories of linear and non-linear consumers. This survey highlights study and analysis of the effects of harmonics on winding losses and core losses of transformer and life expectancy of lightening arrestor.

1.2.1. Transformers

Transformers are designed to deliver the required power to the connected loads with minimum losses at fundamental frequency. The effect of harmonics on transformer is twofold, current harmonics cause an increase in copper losses and voltage harmonics cause an increase in iron losses. Transformer losses categorized as load losses and no load losses may be further divided by I^2R (Winding loss) and stray losses.

$$P_T = P_L + P_{NL} \tag{1}$$

No load loss: This loss is independent of the load and caused by the induced voltage in the core. It comprises 2 components: hysteresis and eddy current losses [2].The core losses such as iron loss and eddy current loss, being the functions of frequency, are higher at higher harmonics.

$$P_{NL} = H + E = k_h \times f \times B_m^n + k_e f^2 \times B_m^2 \tag{2}$$

Where k_e and k_h are constants of the core material, B_m is the maximum flux density and n =[1.5, 2.5] is material dependent. The effect of harmonic loads on no-load loss is often insignificant since the voltage harmonics are dominated by the fundamental component and hence V_{THD} usually does not exceed 5%.

1.2.2. Lightning Arrestor (LA)

It is observed from survey that the failure of lightning arrestor takes place in the vicinity of harmonic prone area. The healthiness of Lightning Arrestors is determined on the basis of internal resistance of the arrestor and its leakage current. The internal resistance of EHV LA should be more than 20 Mega ohms [4]. This can be ascertained by recording Megger values of LAs. For example, the internal resistance of a 220 kV LA should be more than 25 mega ohms. Leakage current is another important parameter to determine life expectancy of LA i In normal practice, the leakage current of the LA should be less than 300 microamperes. Usually it is found that, the leakage current of the LA (I_L) is about four times the third harmonic current I_3, passing through LA i.e $I_L = 4 \times I_3$ [7].

In harmonic prone area the magnitude of the third harmonic current, I_3 is very high. This results in very high magnitude of leakage current. If it is more than 300 microamperes, the chances of failure of LA are more [6].

Power Quality monitoring and analysis was performed and results are calculated in the form of indices. Objective of derived Power Quality Indices is to qualify Distribution Network against the Distortion Index. In this regard, a new procedure is presented that evaluates the Distortion Index introduced by different types of non-linear loads connected to the power distribution network. In presence of Harmonics, the voltage and current functions with respect to time can be expressed as

$$V(t) = V_{0+\sqrt{2\sum_{H\neq 0}^{\infty} V_H \sin(H\omega t + \propto_H)}} \tag{3}$$

Where V(t): instantaneous voltage.V_0: average value,

V_H: rms value of voltage harmonics H.

α_H: phase angle of voltage harmonic H.

$$i(t) = I_{0+\sqrt{2\sum_{H\neq 0}^{\infty} I_h \sin(H\omega t + \beta_H)}} \tag{4}$$

$\bullet_H$: phase angle of current harmonic H

Separating the fundamental component V_1 and I_1 from the harmonic component V_H and I_H gives

$$V = \sqrt{V1^2} + V_H^2 \tag{5}$$

$$I = \sqrt{I1^2} + IH^2 \tag{6}$$

Total Harmonic Distortion Voltage VTHD = VH/V1 (7)

Total Harmonic Distortion Current ITHD = IH/I1 (8)

Fundamental Apparent Power, FAP = V1 I1 (9)

Current Distortion Power, $CDP = V1$ IH (10)

Voltage Distortion Power, VDP = VH I1 (11)

Harmonic Distortion Power, $HDP = VH\ IH$ (12)

Non-linear Apparent Power: $NAP = \sqrt{CDP^2} + VDP^2 + HDP^2$ (13)

Total Apparent Power; $TAP = \sqrt{FAP^2} + NAP^2$ (14)

Distortion Index; DI: $DI = {}^{NAP}\!/_{FAP} * 100$ (15)

As compared with the available THD as Power Quality parameter, it reflects either the voltage or current distortion only. But DI as Power Quality index directly relates to the distortion in power. Hence it is important to include DI as major index which measures the levels of the harmonic pollution present to evaluate the Power Quality performance of the distribution network. This index can also be used as “Quality factor” or “Penalty Factor” [5].

2. OPERATIONAL FEATURES OF SUBSTATION MONITORING SYSTEM (SMS)

In this regard, an Object Oriented Web Enabled (OOWE) method is used to develop Sub-station Monitoring System (SMS) which evaluates the Distortion Index introduced by different types of non-linear loads connected to the power distribution network [6]. Fig. 1 comprises two main applications, Sub-Station client application and Substation Server Application. This will install on each substation. This Application will show all the sub-station along with the monitoring report of each sub-station as per the selected time period. This Monitoring Report includes the PQ Parameters, Power Quality Indices, and Power Quality Distortion Index as per 1st to 9th harmonics.

Server side web application deployed in web server accessible through internet. To deploy this server application, cloud server on the internet is used. User Administrator or sub-station manager will access this application through browser like Internet Explorer/Mozilla Firefox/Google Chrome as web application so that non-technical authority can access or login into Substation Monitoring System.

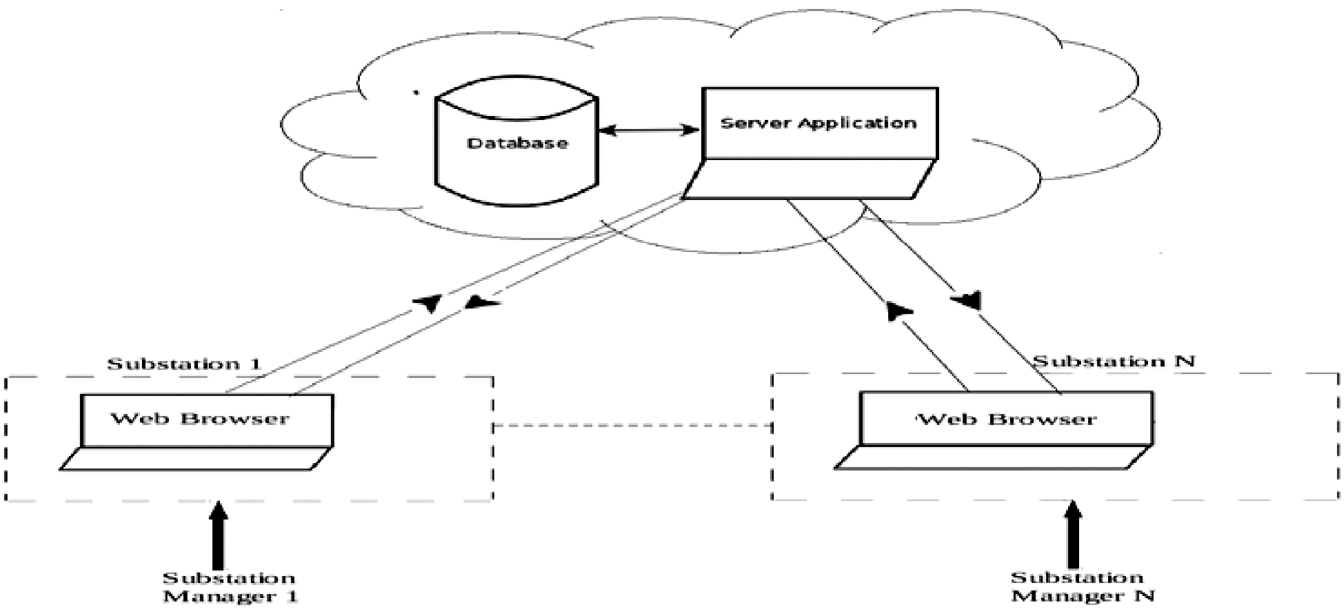


Figure 1: Block diagram of Substation Monitoring System.

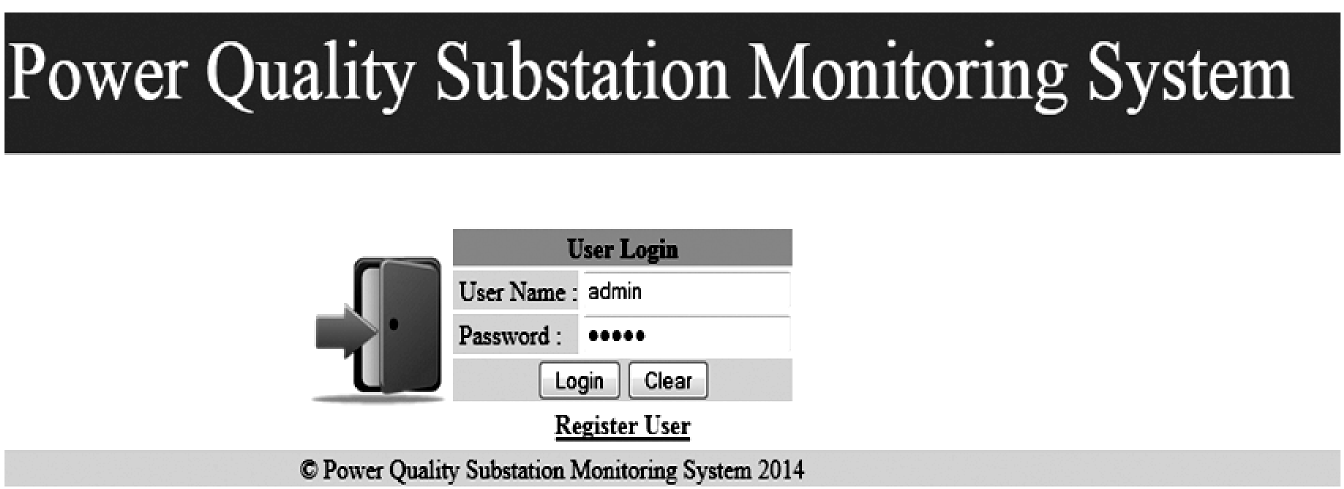
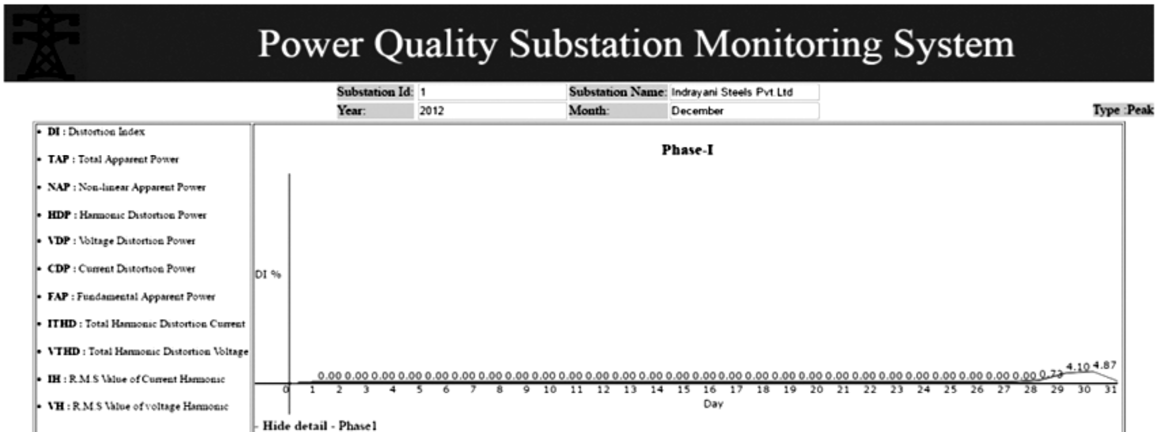


Figure 2: Shows the Web page set up for login to Substation Monitoring System (SMS)

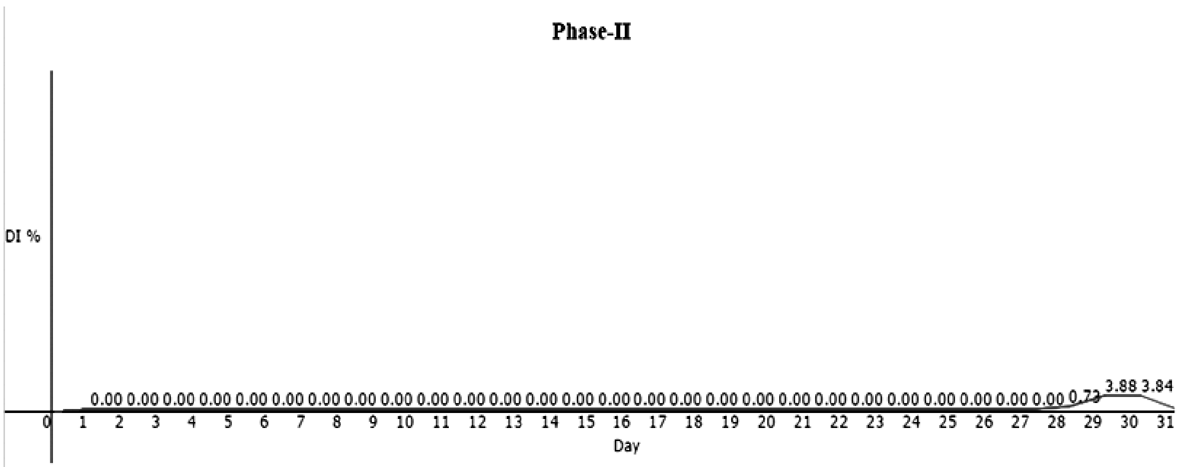
3. FLOW OF SUBSTATION SERVER APPLICATION.

There are two types of users, Administrator& Substation Manager who can access sub-station server application Administrator of server application will be single whereas sub- Substation Manager will be multiple depend on the number of substation. Administrator can create virtual information of substation. This procedure will create list of sub-station and provide access to particular user. It also creates users for each sub-station will be available in a database to maintain the list of sub-station. Each sub-station's information contains sub-station name, address (location), Single Line Diagram Description. This system will monitor and analyze the Power Quality Parameters of each substation as per IEEE Standards.



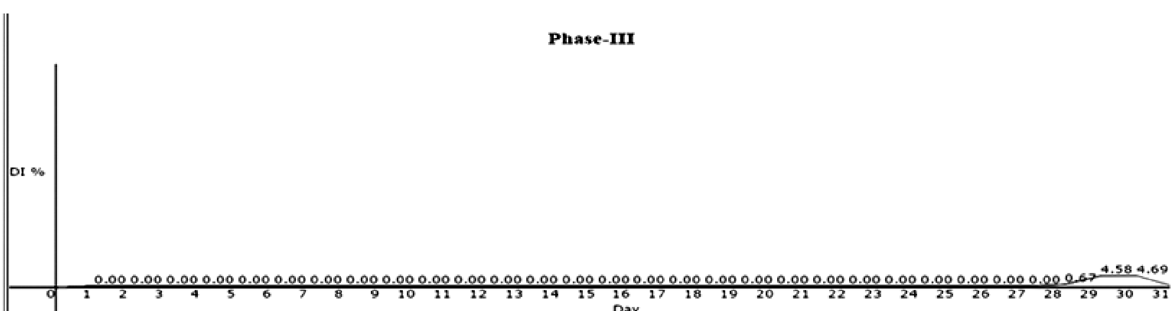
Sr.	Date/Time	DI(%)	TAP	NAP	HDP	CDP	VDP	FAP	THDV	THDI	VH	IH	V	I
1	2012-12-30 00:00:00.0	4.87	3,003.55	146.05	2.31	137.03	50.48	3,000	0.02	0.05	2.52	0.91	150	20
2	2012-12-29 00:00:00.0	4.1	3,002.52	123.02	1.72	114.41	45.17	3,000	0.02	0.04	2.26	0.76	150	20
3	2012-12-28 00:00:00.0	0.73	3,000.08	22	0	0	22	3,000	0.01	0	1.1	0	150	20

Figure 3: Display of Distortion Index in Substation Monitoring System for Phase -I



Sr.	Date/Time	DI(%)	TAP	NAP	HDP	CDP	VDP	FAP	THDV	THDI	VH	IH	V	I
1	2012-12-30 00:00:00.0	3.84	3,002.21	115.14	1.38	108.6	38.21	3,000	0.01	0.04	1.91	0.72	150	20
2	2012-12-29 00:00:00.0	3.88	3,002.26	116.41	1.45	109.42	39.7	3,000	0.01	0.04	1.98	0.73	150	20
3	2012-12-28 00:00:00.0	0.73	3,000.08	22	0	0	22	3,000	0.01	0	1.1	0	150	20

Figure 3a: Display of Distortion Index in Substation Monitoring System for Phase -II



Sr.	Date/Time	DI(%)	TAP	NAP	HDP	CDP	VDP	FAP	THDV	THDI	VH	IH	V	I
1	2012-12-30 00:00:00.0	4.69	3,003.3	140.75	2.09	132.59	47.2	3,000	0.02	0.04	2.36	0.88	150	20
2	2012-12-29 00:00:00.0	4.58	3,003.15	137.47	2.12	128.14	49.72	3,000	0.02	0.04	2.49	0.85	150	20
3	2012-12-28 00:00:00.0	0.67	3,000.07	20	0	0	20	3,000	0.01	0	1	0	150	20

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Figure 3b: Display of Distortion Index in Substation Monitoring System for Phase -III

Table 1
Calculated Indices for different substations.

Power Quality Substation Monitoring System

Indices	*R*	*Y*	*B*
$\%V_{THD}$	1.68905	0.99535	1.389165
$\%I_{THD}$	17.17866	15.65746	15.66782
FAP	125.2349	136.9234	134.6265
CDP	21.51368	21.43872	21.09304
VDP	2.115275	1.362867	1.870183
HDP	0.363376	0.21339	0.293017
NAP	21.62048	21.48306	21.17781
TAP	127.0875	138.5985	136.282
DI	17.26393	15.68984	15.73079

4. CONCLUSION

Fig 1, 2, 3 and Table 1, shows Sub-Station Monitoring System (SMS) display a report regarding Power Quality represents the harmonic indices that give contribution of each load on the total distortion of the power system. It includes distortion of voltage, current, power, total apparent power and also nonlinear apparent power. Therefore, this system set the basis of monitoring and analysis of Power Quality for distribution network.

The case studies presented here are the sample examples and it is necessary to improve the existing situation of Power Quality. The study leads to the following conclusions.

- Electric utility must be able to evaluate, characterize and access the system performance to plan the system improvements for satisfying the Power Quality needs.
- To track the performance of the system, it is important to consider Power Quality indices as one of the method of deciding the Power Quality.
- By creating classes and objects, it possible to conduct simultaneous monitoring and analysis of substations using OOWE method. Therefore, this system set the basis of Monitoring and Analysis of Power Quality for distribution network.

It acts like a “Black Box” on an airplane to tell you what, when, and where a Power Quality event occurred to prevent it from reoccurring.

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REFERENCES

[1] Ewald F. Fuchs, Mohammad A.S. Masoum, A book on “Power quality in power systems and electrical machines”.

[2] Joss Arrilaga, Neville R. Watson, A book on “Power System Harmonics”, WILEY , 2nd edition.

[3] Roger C. Dugan, Mark F. Mc Granghan,A book on “ Electrical power system Quality”,Tata Mcgraw Hill,2nd edition.

[4] IEEE Std. 519-1992 :-IEEE Recommended Practices and Requirements for Harmonic Control in Electrical Power Systems.

[5] Vlahinic, S. Brnobic, D. Stojkovic, N. “Indices for Harmonic Distortion Monitoring of Power Distribution Systems” Instrumentation 12-15 May 2008.

[6] IEEE STD 1159-1995, IEEE Recommended practice for monitoring electric power quality.

[7] MPEB technical report No.124,Research Scheme on Power, June 2000,Study of Harmonic present in the system and determination of permissible limits of harmonics

[8] IEEE working group, “Practical Definitions for powers in systems with non-sinusoidal waveforms and unbalanced load: A Discussion”, IEEE transactions on Power Delivery, vol. 11, No.1,Jan 1996.

[9] Shubha Pandit, S.A.Soman, S.A. Khaparde, “Object Oriented Design for Power System Applications”, IEEE transaction on Power Delivery, Oct 2010.