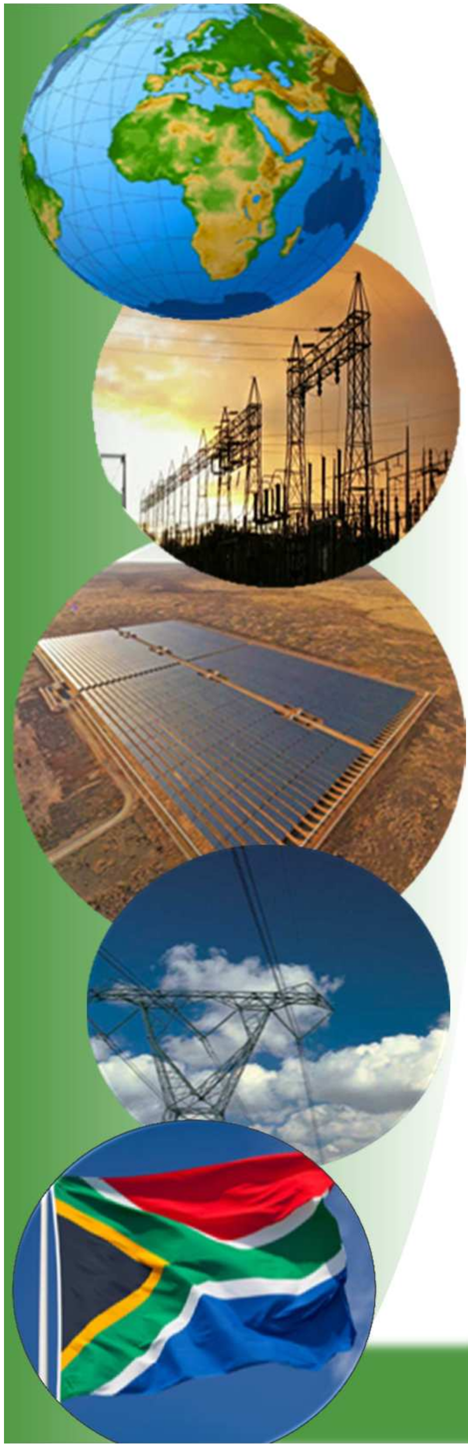

Transformer oil degradation on PV plants – A Case Study

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Introduction

- Renewable energy sources such as PV plants are gaining popularity
- PV power plants generate electricity through solar radiation
- There are fluctuating load patterns experienced by the electrical equipment
- The PV transformer has to have the capability to handle this fluctuating nature
- Oil filled transformers may experience oil degradation due to a number of factors
- Oil Analysis is done for critical oil filled transformers in service
- DGA is a tool used for oil and transformer condition assessment
- Particular faults can be determined through the interpretation of DGA results – partial discharge, electrical faults, thermal faults etc.
- Interpretation tools such as IEC and IEEE key gas ratios, Duval analysis and Cigre are utilised in DGA interpretation

Case Study

- A case study was conducted on several transformers at 3 different PV plants
- The transformers had been exhibiting abnormal gassing patterns
- Oil samples were collected at different intervals and DGA was done to trace the gassing patterns
- Key gas ratios and Duval analysis were used to interpret the DGA results
- Oil quality indicators were also investigated

Results - DGA

DGA oil sample results (ppm)

Transformer Unit	H_2	O_2	N_2	CO	CO_2	CH_4	C_2H_4	C_2H_6	C_2H_2	TCG
North West PV plant (NW)										
Unit NW1	9671	5904	65918	84	978	1963	N/D	559	N/D	12277
Unit NW2	9345	6281	78245	166	2098	1488	8	276	N/D	11283
Unit NW3	10000	4462	61212	70	808	2481	5	637	N/D	14110
Northern Cape PV plant A (NCA)										
Unit NC1	1478	28899	72484	28	860	438	36	561	N/D	2541
Unit NC2	1562	26189	68661	33	965	417	13	619	N/D	2644
Unit NC3	1598	32311	78590	1	835	543	132	479	N/D	2753
Northern Cape PV plant B (NCB)										
Unit NCB1	1334	1901	77903	101	1839	270	74	578	N/D	2373
Unit NCB2	2203	1715	78185	128	1795	594	5	838	N/D	3768
Unit NCB3	1953	2410	73352	117	1870	467	N/D	785	N/D	3322

Results – DGA (cont..)

Calculated key gas ratios

Transformer Unit	CO_2/CO (Temperature Fault<150)	O_2/N_2 (Oxygen Consumption)	C_2H_2/C_2H_4	C_2H_6/H_2
Unit NW1	11.64	0.09	N/D	0.058 /*D1*
Unit NW2	12.64	0.08	0	0.030 /*D1*
Unit NW3	11.54	0.073	0	0.064 /*D1*
Unit NCA1	30.71	0.40	0	0.380 / *Thermal*
Unit NCA2	29.24	0.38	0	0.40 / *Thermal*
Unit NCA3	835	0.41	0	0.30 /*Thermal*
Unit NCB1	18.21	0.024	0.22	0.433 /*Thermal*
Unit NCB2	14.02	0.022	0	0.380 /*Thermal*
Unit NCB3	15.98	0.033	N/D	0.401 /*Thermal*

Results – DGA (cont..)

Duval analysis

Transformer Units	Duval analysis				
	Tria. 1	Tria. 4	Tria. 5	Pent. 1	Pent. 2
Unit NW1	PD	S	S	S	S
Unit NW 2	PD	S	S	S	S
Unit NW 3	PD	S	S	S	S
Unit NCA1	T1	S	O	S	S
Unit NCA2	T1	S	O	S	S
Unit NCA3	T1	S	Non-determinable	S	S
Unit NCB1	T2	S	O	S	S
Unit NCB2	PD	S	O	S	S
Unit NCB3	PD	S	S	S	S

Results – Oil Deterioration Factors

Dielectric strength (Class B)

Transformer Unit	Measured value (kV)		Limit – IEC 60156 (kV)
	Previous sample	Current sample	
Unit NCB1	59	31	≥30
Unit NCB2	87	74	≥30
Unit NCB3	74	83	≥30

Water/moisture content (Class B)

Transformer Unit	Measured value (ppm)		Limit – IEC 60814 (ppm)
	Previous sample	Current sample	
Unit NCB1	27	27	≤40
Unit NCB2	11	10	≤40
Unit NCB3	10	20	≤40

Interfacial tension (Class B)

Transformer Unit	Measured value (mN/m)		Limit – ISO 6295 (mN/m)
	Previous sample	Current sample	
Unit NCB1	14	14	≥20
Unit NCB2	26	25	≥20
Unit NCB3	15	14	≥20

Results – Oil Deterioration Factors (cont..)

Dielectric dissipation factor (tan delta) (Class B)

Transformer Unit	Measured value (at 90°C)		Limit – IEC 60247 (at 90°C)
	Previous sample	Current sample	
Unit NCB1	0.22370	0.1888	≤0.50
Unit NCB2	0.00842	0.01333	≤0.50
Unit NCB3	0.18410	0.1262	≤0.50

Acidity (Class B)

Transformer Unit	Measured value (mg KOH/g)	Limit – IEC 62021-1 (mg KOH/g)
Unit NCB1	0.19	≤0.30
Unit NCB2	0.01	≤0.30
Unit NCB3	0.12	≤0.30

Results – After Oil Replacement

DGA oil sample results after oil replacement (ppm)

Transformer Units	H_2	O_2	N_2	CO	CO_2	CH_4	C_2H_4	C_2H_6	C_2H_2	TCG
NW										
Unit NW1	472	19807	73610	90	2569	160	3	312	0	1037
Unit NW2	1445	41742	94188	42	1373	360	0	353	0	2200
Unit NW3	460	26891	76630	70	2118	186	3	322	0	1041
NCA										
Unit NCA1	150	19455	90800	89	2291	84	0	222	0	545
Unit NCA2	474	22808	81303	95	2053	93	0	204	0	866
Unit NCA3	294	36284	78810	37	1287	73	0	213	0	617
NCB										
Unit NCB1	369	7481	94422	243	6191	171	10	673	0	1466
Unit NCB2	657	4855	76973	249	4246	312	8	798	0	2024
Unit NCB3	455	6447	79188	241	4429	199	8	457	0	1360

Conclusion

- The abnormal gassing patterns were mainly observed during high solar radiation months
- The oil analysis showed evidence of potential oil degradation as a result of thermal stress, possibly – hotspots in metallic parts
- Material compatibility issues were suspected – compatibility tests proved inconclusive
- Oil degradation plays a part in the gassing activity of the transformer as evidenced by the replacement of the oil

Recommendations

- Thorough harmonic studies for PV plants should be done
- Proper transformer specifications should be agreed upon by both OEM and customer, with possibly reclassifying generator step-up transformers to industrial transformers instead of distribution transformers
- More adequate design philosophies to be adopted – such as the use of forced and/or directed cooling to reduce localised heating
- Consideration of more moisture tolerant transformer oils and cellulose materials – to accommodate the wide temperature gradients seen by transformers in PV applications