Digitalization of **TGP Oil Immersed Power Transformers**

By: **Faisal Alaam, Arun Nair, Assaf Barrag**

Introduction:

Technologies of the Fourth Industrial Revolution (4IR) are reshaping the global economy, including energy. In 2017, Saudi Aramco (SA) embarked on journey of the digital transformation aiming to become the world's leading digitalized energy corporation by spearheading the digital innovation in energy sector. In line with this vision, Tanajib Gas Plant Projects Department (TGPPD) implemented digitalization on oil immersed power transformers. Tanajib Gas Plant (TGP) has twenty-six (26) 230kV/13.8kV transformers (8 rated 60/80MVA and 18 rated 75/100MVA) and all are fitted with advanced Condition Monitoring System (CMS). To realize the full benefits of digitalization, transformer CMS will be integrated with the plant Power System Automation (PSA).

Condition Monitoring System

Condition monitoring is a technique or a process of monitoring the operating characteristics of equipment in such a way that changes and trends of the monitored characteristics can be used to predict the need for maintenance before serious deterioration or breakdown occurs. CMS can estimate the machine's "health" by detecting early signs of degradation in various components and provide warning to operator to avoid extended and expensive outages due to catastrophic failure. Typical CMS system monitoring in power transformers are listed in Figure-1. The data from transformer CMS will be connected to Power System Automation (PSA) which is monitored by the plant operator in control room.

Monitoring System	Features/Functions
Transformer	○ Monitoring the oil temperature ○ System voltage, load current, frequency, load factor, active power, reactive power, apparent power ○ Calculation of aging rate and loss-of-life ○ Tap position capture
Cooling	○ Number of starts per cooling level ○ Operating time per cooling level
On Load Tap Changer (OLTC)	○ Maintenance recommendations and maintenance interval calculation for OILTAP. ○ Tap-position statistics for the OLTC (number of tap-change operations/tap, duration per tap) ○ Monitoring of OLTC oil temperature
Bushing	○ Monitoring of changes in C1 capacitance ○ Monitoring of the dissipation factor (tan δ) ○ System voltage
Online Dissolved Gas Analysis (DGA)	○ Online recording of gases, relative moisture in oil and relative overall gas content ○ Configurable limit value for each gas ○ Curve display of the measured value

Figure-1 CMS System for Power Transformer

TGP Power Transformers CMS

In TGP transformer, CMS system installed monitors the following components: Dissolved Gas Analysis (DGA), Cooling System, On-Load Tap Changer (OLTC), and Transformer. Details of each monitoring system are discussed below:

Dissolved Gas Analysis (Dga) Monitoring

Transformer oil contains almost 70-80% of the transformer health information. When a thermal or electrical fault occurs in a transformer, the oil and paper insulation will break down generating gases that dissolve back into the insulating oil. DGA is a very efficient and reliable tool for the earliest detection of inception faults in transformer and other electrical equipment using insulating oil. The DGA procedure consists of extracting and analyzing the gases from the oil. The type and proportion of the gases present in oil indicates the nature and severity of the fault. DGA monitoring, implemented in TGP oil immersed power transformers, consists of online recording of the two gases (Hydrogen H2), Carbon Monoxide (CO)), relative moisture content and relative overall gas content. The H2 content is an indicator of thermal

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and electrical faults damages in the transformers. On the other hand, CO concentration in the insulating oil indicates the damage to the paper insulation and moisture content indicates the aging and decomposition of the insulation materials.
The trends and rate-of change of these cases based on the monitoring provides early detection warning for the type of faults and its severity.

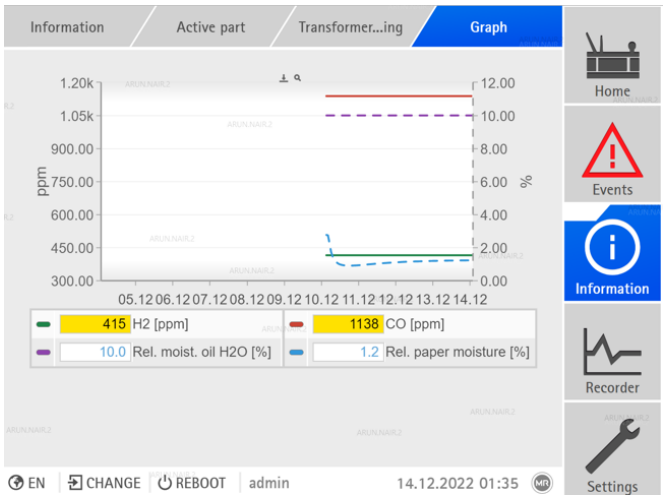

Figure-2 HMI screenshot of DGA monitoring of the gases and moisture level

Cooling System Monitoring

In cooling monitoring system, cooling fans operation is monitored to determine if they are working when they are required to be ON. This is achieved by measuring the currents drawn by each fan and cross checking them with expected ON/OFF status based on winding temperature limits. The abnormal operation of the fans indicates faults in the control and power wiring. The fans group current drawn are monitored also to detect the overload indication of the fans.
Cooling monitoring system also monitors the number of starts for fans per cooling period and also the operation time per cooling period. This will be co-related with the loads and temperature to predicts any issues with the transformers.

Oltc Monitoring

Onload Tap Changer (OLTC) failures are results of mechanical or electrical faults. To identify these faults at early stage, several parameters are monitored for OLTC which include: drive mechanism motor current, temperature difference between the OLTC compartments and the main tank, time since last through neutral, accumulated contact wear, mechanism operating time, and mechanical vibrations. Based on monitoring of these parameters, predictive and regular maintenance messages are displayed in the Human Machine Interface (HMI) of the CMS system (Figure-4).

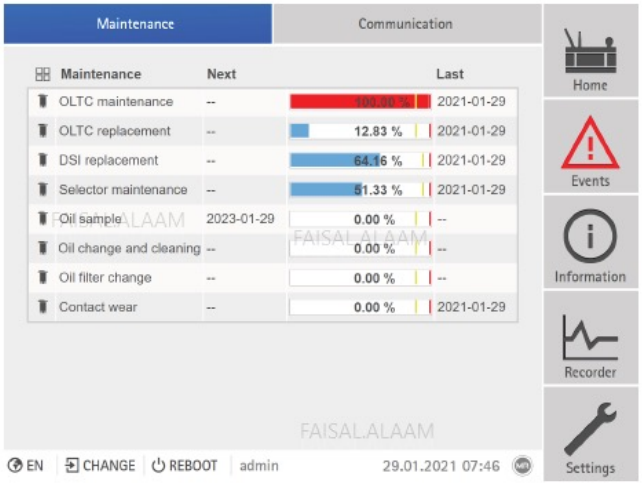

Figure-3 HMI screenshot of preventive maintenance messages for OLTC

Tranformer Monitoring

As part of the transformer monitoring function package, the top oil and ambient temperatures are monitored. Also, it provides the hot-spot temperature calculation and forecast.
Monitoring of these parameters helps for early detection of electrical faults and provides

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maintenance messages. Also, it calculates the loss of life and relative aging of the transformers which helps the operator (Figure-4) to take decision regarding the need for transformer repair or replacement

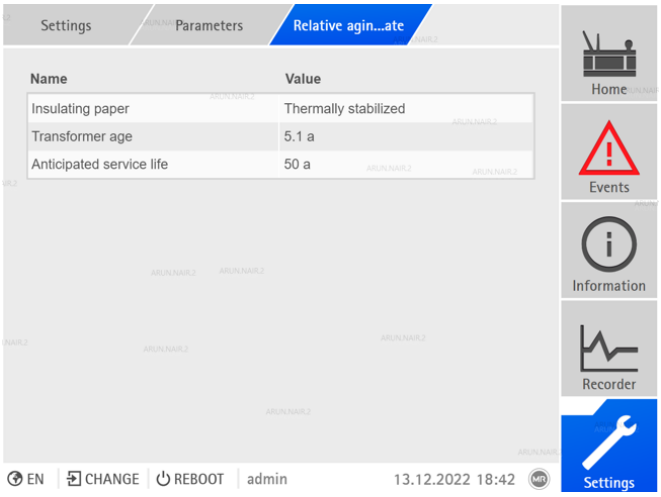

Figure-4 HMI screenshot sample for the relative aging and

CMS and PSA Integration

CMS panel installed on the transformer in field, is equipped with HMI display which provides the operator an access to CMS system screens for all the details. Also, the provision of local access through a laptop is available in the CMS panel. However, since substations are designed to be unmanned, the CMS system is integrated to the Power System Automation (PSA).
The CMS of the power transformer is connected to the substations' PSA system, through IEC-61850 communication protocol, which is then connected to the main TGP PSA system located inside Central Control Building (CCB) where the critical signals and alarms from the CMS system are monitored by the operator. The operator will be notified for predictive maintenance requirements based on the inputs received from the CMS to prevent major transformer failures and extended shutdown.

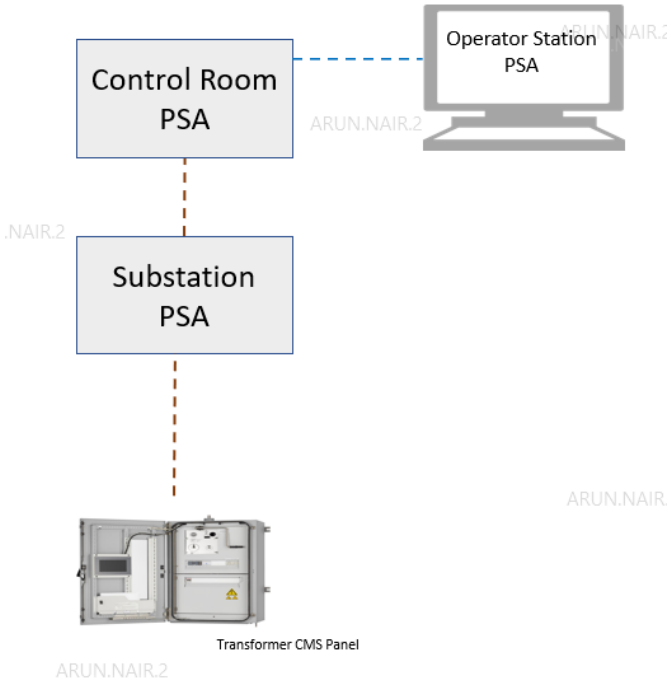

Figure-5 CMS connection to PSA system

Implementation Of CMS For Power Transformers In Future Sa Projects

This technical paper covers the implementation CMS for the major components in TGP power transformers excluding bushing monitoring system. Bushing monitoring system was not implemented due to project schedule impact due to very long cables for refence voltage between the upstream switchgear and the transformers. However, SA recommends implementation the complete CMS system, including bushing monitoring, as part of substation digitalization in all the future projects.