- Read and set operating parameters
- Monitor each zone in real time
- Daily Log of Current-On, & Instant-off steel potentials at set time intervals
- Conduct global depolarization tests at set intervals
- Retrieve & analyze depolarization data
- Provide criteria compliance summary of all zones
- DC output status screen
- Alarm enabling
- Set high/low limits

3. SYSTEM COMMISSIONING, MONITORING, & PERFORMANCE ASSESSMENT

3.1 Initial Energizing

All zones of CT-A, CT-B (except zone 6A, & 9A), and Pump Basin (PB) were energized in June 2010. The systems were powered in constant current mode at an applied steel current density of 2.5mA/m^2 (50% of design current density). Later on the current was increased, where required to achieve protection criteria. But due to some site obstructions, CT-B zones were turned off and then all zones of CT-B were re-energized in October 2010. Prior to initial energizing, natural potentials were measured (every 2-3 weeks after completion of concrete pour until initial energizing) and established at the location of all embedded reference electrodes in all zones.

3.2 System Monitoring & Assessment

The following two criteria (European Standard BS EN ISO 12696) are used for assessing the effectiveness of the cathodic prevention systems of CTs & PB.

- 100 mV potential decay from instant-off in 24 hours after current interruption.
- An instant-off potential more negative than –720 mV Ag/AgCl.

The CT-A results (from latest monitoring) are summarized in Table 4 and Fig. 4 below.

Table 4:- Summary of criteria compliance for Cooling Tower A.

Exposure	**Zones Nos.**	**Applied Steel Current Density mA/m^2**		**REs Nos.**	**CP System Criteria Compliance**	
		Ranged	**Average**		**RE (Nos.)**	**RE (%)**
Buried	25	3.7 to 6.0	5.0	175	128	**73%**
Submerged	27	2.5 to 6.0	5.3	234	202	**86%**
Humid	24	2.5 to 6.0	5.2	170	148	**87%**
Atmospheric	34	2.5 to 7.2	4.3	238	201	**84%**

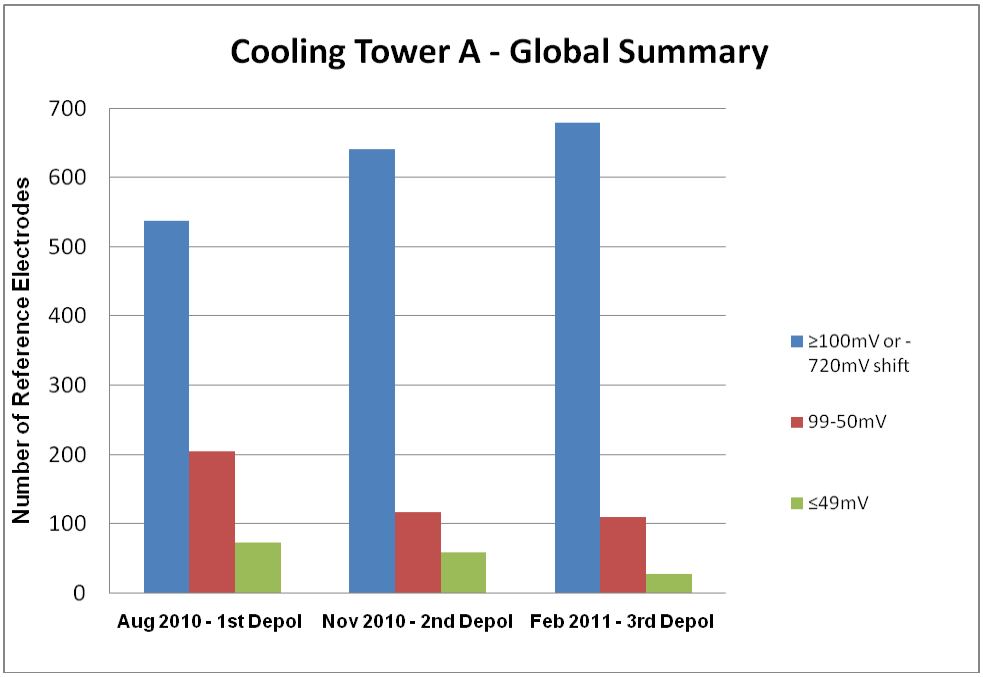

Fig. 4: Summary of criteria compliance with time for CT-A.

The results show that 679 REs (83%) achieved the protection criteria, a further 110 REs (14%) achieved a depolarization between 99mV & 50mV and 28 REs (3%) achieved 49mV or below, out of the total of 817 REs. The global summary of results shown in Fig. 3 below indicates that criteria compliance improved with time.

The applied steel current densities ranged between 2.5 and 7.5 mA/m^2, whereas the average values were quite close to the design steel current density and ranged between 4.3 and 5 mA/m^2. As the polarization growth is increasing gradually with time, it is expected that 100% criteria compliance would be achieved within a few months and this would then be followed by a gradual reduction in applied current levels.

The CT-B results (from latest monitoring) are summarized in Table 5 and Fig. 5 below.

Table 5:- Summary of criteria compliance for Cooling Tower B.

Exposure	**Zones Nos.**	**Applied Steel Current Density mA/m^2**		**REs Nos.**	**CP System Criteria Compliance**	
		Range	**Average**		**RE (Nos.)**	**RE (%)**
Buried	25	2.5 to 4.5	3.2	175	128	**73%**
Submerged	27	2.5 to 4.1	3.3	235	195	**83%**
Humid	24	2.5 to 5.0	4.2	170	112	**66%**
Atmospheric	34	2.5 to 5.0	3.4	238	159	**67%**

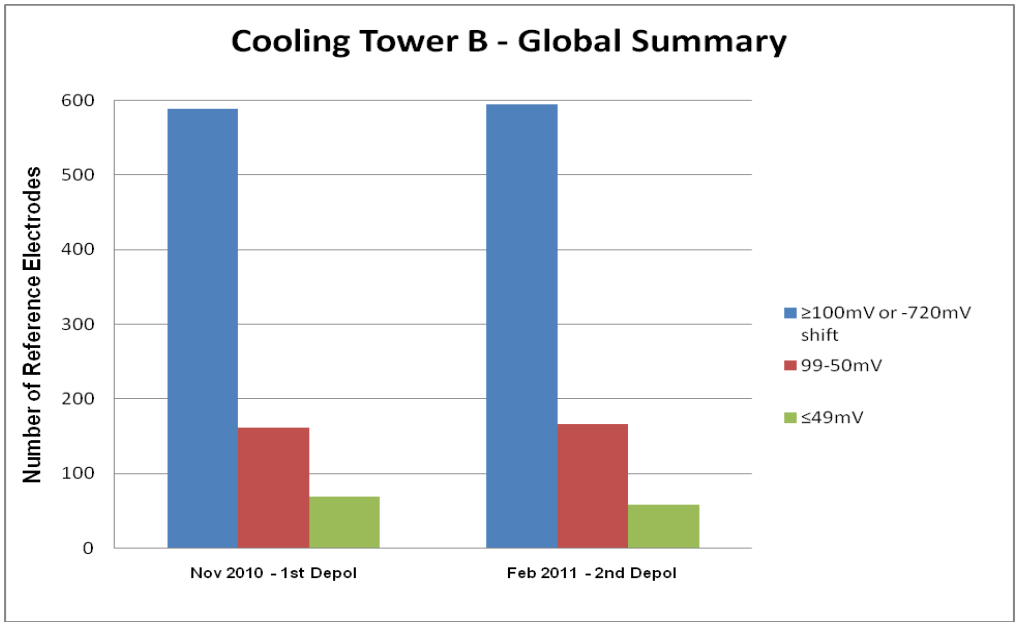

Fig. 5: Summary of criteria compliance with time for CT-B.

The result shows that 594 REs (73%) achieved the protection criteria, whereas 166 REs (20%) achieved a depolarization between 99mV & 50mV and 58 REs (7%) achieved 49mV or below, out of the total of 818 REs. The applied steel current densities ranged between 2.5 and 5mA/m^2, and the average values ranged between 3.2 and 4.2mA/m^2. The global summary of results shown in Fig. 4 above indicates that there was no significant change with time with regard to criteria compliance. Hence, the applied current level was increased in many zones, particularly for humid and atmospherically exposed areas. This should accelerate the cathodic polarization growth and it is expected that 100% criteria compliance would be achieved within 4-6 months. Following that applied currents can be reduced gradually.

The PB results (from latest monitoring) are summarized in Table 6 above and Fig. 6 below.

Table 6:- Summary of criteria compliance for Pump Basin.

Exposure	**Zones Nos.**	**Applied Steel Current Density mA/m^2**		**REs Nos.**	**CP System Criteria Compliance**	
		Range	**Average**		**RE (Nos.)**	**RE (%)**
Buried	9	3.8 to 6.6	5.2	63	56	**89%**
Submerged	6	2.5 to 5.5	4.3	46	46	**100%**
Humid	2	3.2 to 6.5	4.9	14	14	**100%**
Atmospheric	4	4.4 to 5.5	4.6	22	20	**91%**

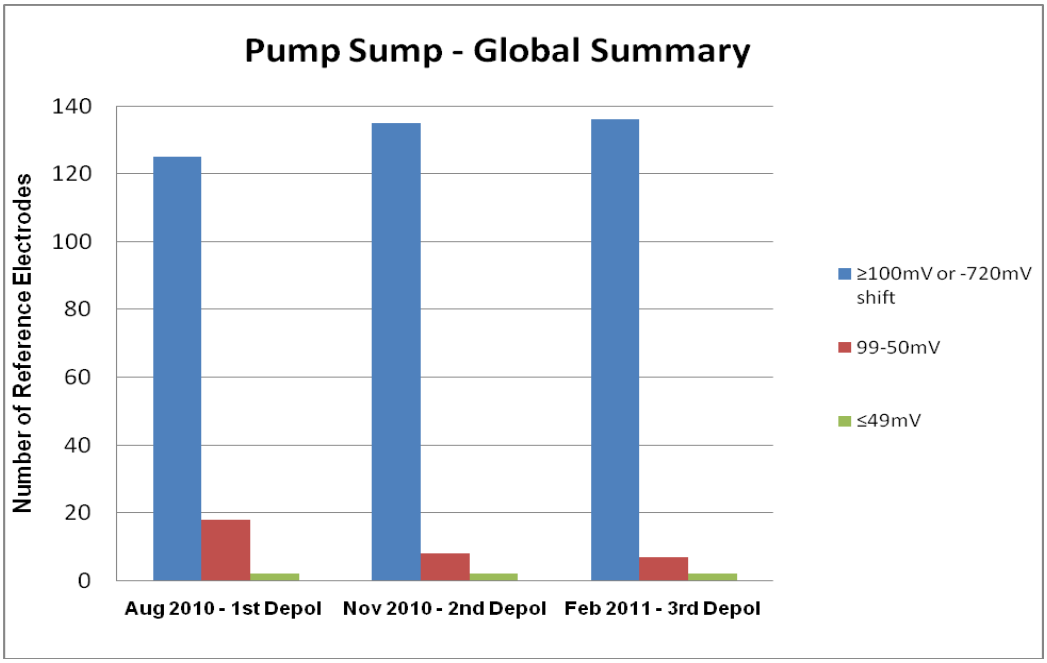

Fig. 6: Summary of criteria compliance with time for Pump Basin.

The results show that 136 REs (94%) achieved the protection criteria, whereas 7REs (5%) achieved a depolarization between 99mV & 50mV and 2 REs (1%) achieved 49mV or below, out of the total of 145 REs. The global summary of results shown in Fig. 8 above indicates that criteria compliance improved with time. The applied steel current densities ranged between 2.5 and 6.6 mA/m^2, whereas the average values were quite close to the design steel current density and ranged between 4.3 and 5.2 mA/m^2. As the polarization growth is increasing gradually with time, it is expected that 100% criteria compliance would be achieved within few months and following that applied currents can be reduced gradually.

4. Conclusions

The cathodic prevention systems for 2 very large size cooling towers and a pump basin have been successfully installed and commissioned. The monitoring data gathered during the 6-9 months after the initial energizing of the CP systems have shown that the specified criteria have already been met at 1409 (79%) monitoring locations out of the total of 1780(for all 3 structures). At several locations where the criteria have not been achieved so far, the depolarization was recorded between 80mV and 99mV.

The monitoring data trend has suggested that polarization growth in the negative direction is gradually increasing with time. This implies that the overall CP system is meeting its design objectives in preventing corrosion of the reinforcing steel in these seawater structures.

Applied average steel current densities required to achieve adequate protection in different exposures of all 3 structures have ranged between 3.2 and 5.3 mA/m^2 and

generally were very close the to the design current density (5 mA/m^2). This shows that designing CP systems for seawater structures in very hot and humid environments using 5 mA/m^2 steel current density would be a better and a safer approach than the rang recommended in the European Standard. As the polarization growth is increasing gradually with time, it is expected that 100% criteria compliance would be achieved within few months and then the required applied current levels could be reduced with time.

The power supply and remote monitoring system that was specifically designed and customized for this project has proved to be not only a useful but an essential tool for monitoring, assessing and controlling such a huge CP system. Without this RMS, CP systems of this size and application cannot be monitored and assessed so effectively and accurately.

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