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Engineering Technology Far-end Telecontrol Cathodic Protection on the Structure of Jetty Bridge Cap Beams

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23 cap beams on the 1 Km length jetty bridge in Shin-da power plant (Taipower co., Taiwan) utilize far-end telecontrol cathodic protection technology which is the first case ever used in Taiwan. The system comprises cathodic protection system and telecontrol monitoring system. The control and monitoring such as protection current adjustment, protection potential and depolarization measurement of the 23 cap beams can be adjusted through system telecontrol operations. Thereby allows monitoring and control of the 23 anode zones in a convenient and cost effective way. This system is at present still in its best running condition since Sept. 1997 when it was completed. All the 23 cap beams can achieve the 100 mV depolarization potential criteria of protection. It meet the specifications of reinforced concrete cathodic protection standard and proved to be very excellent.

Keywords : *cathodic protection, rebar, far-end telecontrol, corrosion*

1. Introduction

The jetty bridge of Shin-da coal dockyard(Taipower co., Taiwan) was found suffering severe rebar corrosion through field inspection and evaluation of the bridge safety and serviceability condition in 1996. Large areas of spalled and delaminated concrete with high chlorine ions content in concrete were detected especially at the bottom face of the cap beams. At some area chlorine ions content even reaches 25 times higher than the threshold value 0.3 kg/m^3 specified in the CNC3090 standard.

Cathodic protection system was selected as the rehabilitation technique for the 23 cap beams on the 1 km length jetty bridge. To give long time life extension with efficient maintenance far-end telecontrol is utilize to constant assess the status of protection on each cap beam and make adjustment. This approach is the first case ever to use in Taiwan and is at present still in its best running condition since Sept. 1997 when it was completed. The use of cathodic protection reduced significantly the amount of necessary concrete repairs. The far-end telecommunication control system allows monitoring and control of the 23 anode zones in a convenient and cost effective way.

2. The method of practice[1),2)]

2.1 Design and installation of the system

The necessary practices to the installation of the system includes:

(1) pre-installation survey
(2) system design and computation
(3) repair and surface preparation
(4) negative connections
(5) monitoring electrodes installation
(6) anode installation
(7) cementitious overlay application
(8) electrical installation
(9) control system installation

2.1.1 Pre-installation survey

Pre-installation survey over the entire concrete structure is necessary to provide information for the essential design and repair procedure in order to allot uniform protection current to the reinforcement.

Prior to the installation of the cathodic protection system in this project, assessment were carried out particularly in determining the reinforcement continuity, concrete resistivity, reinforcement distribution, and to locate areas of low and high cover, delamination and metal component attached on concrete surface.

2.1.2 System design

The cathodic protection system includes monitoring system, anode system, electrical system and telecommunication control system. Based on the relative data of the pre-installation survey, the protection current requirement at each area on the cap beams was calculated, from which materials and layout design were decided.

2.1.3 Concrete repair and surface preparation

Concrete at where delaminated and resistivities larger than 20 k-ohm were removed and reinstated to its original profile using cementitious materials. Concrete surface preparation involved cleaning away objects which may affect current distributions such as oil sludge, lacquer, impurities and metal component. The concrete surface then water blast with a pressure of 20K-psi. to give a roughten surface for better adhere of cementitious overlay.

2.1.4 Negative connections

For each anode zone there are at least 2 connections between the negative terminal of the rectifier and reinforcement.

2.1.5 Monitoring electrodes

Each anode zone is monitored by at least 2 embedded Ag/AgCl reference electrodes.

2.1.6 Anode installation

Electrocatalytic coating titanium expanded mesh anode is used in this system. The anode mesh holds onto the concrete surface in place using fasteners. Titanium conductor bars were welded on to the mesh and with positive connection made at the terminals. For each anode zone there are at least 2 connections between the positive terminal of the rectifier and Titanium conductor bars on anode mesh.

2.1.7 Application of cementitious overlay

Application of cementitious overlay was by spraying and trowelling procedure. The thickness of the covering materials is 1.0-1.5 cm to ensure complete encapsulation of the mesh.

2.1.8 Electrical installation

All cables includes AC power cables, DC power cables, reference electrode cables etc. not embedded are laid in conduit and joints in cables are allowed only at junction boxes. They were tested for continuity and correct termination and labeled.

2.1.9 Control system installation

All reference cell cables, positive and negative cables of each anode zone are connected to terminals on the respective local rectifier unit placed near by such that cabling is as short as possible. The local rectifier units for each anode zone are connected to a central control unit.

2.2 Performance verification

Initial energizing of the system was undertaken on completion of installation and after 28 days minimum curing period for the anode system overlay. When the power sources momentarily energized to the designed protection current the direction of potential change on the reinforcement was detected to confirm that the DC output polarity is correctly connected. Measurement was made after DC output adjustment to establish whether the 100 mV depolarization potential criteria of protection are being achieved. The currents of each anode zones should be readjusted until achieved the requirement. The system is then left to operate at this level and performance monitoring was carried out at 3 monthly intervals for the first operation year after which system review was carried out at 12 monthly intervals.

3. Results

3.1 Anode zones

Fig. 1 shows the view of the Shin-da(Taipower) jetty bridge. The jetty bridge consists of 25 equal spans where

Fig. 1. Shin-Da Taipower plant jetty bridge 23 cap beams on cathodic protection.

Table 1. The protection current and area of the respective anode zones

Cap Beam (anode zone)	Area of Protection (m^2, concrete surface)	Designed Protection Current(A)
P3~P6	58	0.63
P7~P8	86	0.90
P9	135	1.43
P10~P12	58	0.69
P13~P15,P19	58	1.00
P16	135	2.46
P17~P18	86	0.86
P20~P22,P24,P25	58	0.94
P23	135	3.38

23 cap beams on bridge pier P3 to P25 are cathodic protected .The total protected area is 1677 m^2 of concrete. Each cap beam is a separate anode zone comprises individual anode system, negative terminals, monitoring systems and power source.

The titanium mesh anode utilized can be operated at 33 mA/m^2 concrete. The designed rebar protection current density on the cap beams range between 10 ~ 20 mA/m^2 surface area of rebar.[3] The designed protection current and protection area of the respective cap beams is shown in Table 1.

3.2 Control system

The 23 anodes zones utilize distributed rectifier system that simultaneously carries out control and monitoring routine from a single location. Each anode zone is power by a specific local rectifier unit placed nearby. The 23 local rectifier units in 13 sets of local rectifier units cabinets are connected to a central control unit from which assess to all local rectifier unit and thereby all anode zones and reference cells. The local rectifier units are software controlled in adjust and read current/voltage output and monitor reference electrode potential. A modem control system installed in the central control unit enables communication from any far-end working station. Fig. 2 shows the sketch of the far-end tele-control system of the cathodic protection system for Shin-da(Taipower) jetty bridge.

3.3 Performance

Energizing of the Shin-da jetty bridge cathodic protection system was undertaken since completion of installation in Sept. 1997. The performance of the system was constantly inspected and controlled from a far-end working station such as the ITRI-MRL 300,000 km away. Table 2 shows the status of protection current and potential of the cathodic protection system.

3.3.1 Polarity conformation

With the power sources energized to the protection currents all the reinforcing steel protection potentials become more negative than its natural potential. This indicated the reinforcement steels are cathodicaly polarized confirmed that the DC output polarity is correctly connected.

3.3.2 Protection current

The protection currents for all anode zones operate within or near the designed current. 100 mV potential decay criteria can be achieved at almost all the Ag/AgCl reference cells embedded points indicate uniformed current distribution to the reinforcing steel within the anode zone. Obviously the system is at present still in its best running condition after 4 years of operation.

3.3.3 Depolarization time

The depolarization potential were obtained by disconnect the power to anode system and record the changes of rebar potential by time as shown in Fig. 4. The potential decay is determined as the difference between the instantaneous current off potential and the depolarized potential during which the system remains off. Most of the anode zones achieve 100 mV potential decay within 4 hours. The depolarization rate of anode zone on P6, P24 and P25 are lower hence their period of potential decay

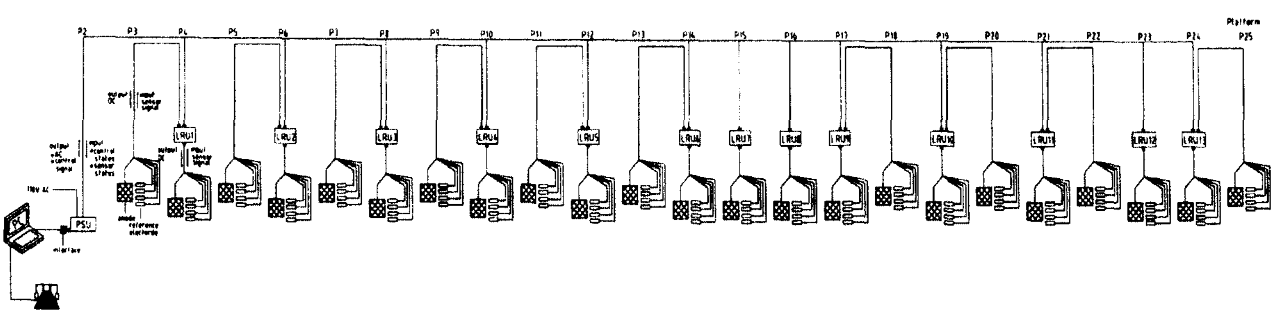

Fig. 2. The sketch of far-end telecontrol cathodic protection system for Shin-Da Taipower jetty bridge cap beams

Table 2. Status of protection current and potential of the respective anode zones

Local rectifier Unit Cabinet NO	LRU 1							LRU 2					LRU 3					
Cap Beam(anode zone)	P3			P4				P5		P6			P7			P8		
DC Output (mA)	400			625				700		700			700			825		
Reference Cell NO.	R1	R3	R4	R1	R2	R3	R4	R2	R3	R1	R2	R4	R2	R3	R4	R1	R2	R3
Natural Potential (-V)	0.43	0.155	0.233	0.053	0.099	0.063	0.273	0.137	0.076	0.043	0.056	0.119	0.013	0.128	0.083	0.101	-0.06	0.082
Protection Current (-V)	0.569	0.869	0.628	1.299	0.485	0.608	1.258	1.209	1.715	0.526	1.398	0.276	0.546	0.667	0.51	0.716	3.357	0.627
Instantaneous off Protection (-V)	0.502	0.529	0.526	0.873	0.327	0.354	0.569	0.609	0.699	0.419	0.493	0.22	0.343	0.38	0.406	0.439	0.626	0.282
4 Hour Potential Decay(-V)	0.381	0.196	0.281	0.741	0.22	0.069	0.318	0.32	0.517	0.172	0.137	0.139	0.149	0.182	0.16	0.266	0.044	0.161
Depolarized potential (V)	0.121	0.333	0.245	0.132	0.107	0.285	0.251	0.289	0.182	0.247	0.356	0.081	0.194	0.198	0.246	0.173	0.582	0.121

Local rectifier Unit Cabinet NO	LRU 4						LRU 5						LRU 6					
Cap Beam(anode zone)	P9			P10			P11			P12			P13		P14			
DC Output (mA)	1000			600			600			600			700		750			
Reference Cell NO.	R2	R3	R4	R1	R2	R4	R1	R2	R4	R1	R2	R4	R1	R4	R1	R2	R3	R4
Natural Potential (-V)	0.095	0.055	0.073	0.088	0.041	0.015	0.078	0.124	0.079	0.048	0.056	0.05	0.113	0.048	0.135	0.242	0.196	0.12
Protection Current (-V)	0.637	0.423	0.7	0.561	0.585	0.369	0.586	0.739	0.596	2.024	0.725	1.307	3.017	0.862	2.304	1.549	3.73	2.331
Instantaneous off Protection (-V)	0.376	0.285	0.526	0.352	0.286	0.289	0.419	0.406	0.46	0.445	0.336	1.025	0.582	0.625	0.665	1.014	1.91	0.394
4 Hour Potential Decay(-V)	0.186	0.15	0.165	0.119	0.1	0.062	0.176	0.2	0.195	0.06	0.116	0.71	0.183	0.206	0.328	0.275	0.918	0.141
Depolarized potential (V)	0.19	0.135	0.361	0.233	0.186	0.227	0.243	0.206	0.265	0.385	0.22	0.315	0.399	0.419	0.337	0.739	0.992	0.253

Local rectifier Unit Cabine NO	LRU 7				LRU 8			LRU 9						LRU 10				
Cap Beam(anode zone)	P15				P16			P17			P18			P19			P20	
DC Output (mA)	600				2000			600			925			925			825	
Reference Cell NO.	R1	R2	R3	R4	R1	R3	R4	R2	R3	R4	R1	R2	R3	R1	R2	R4	R1	R4
Natural Potential (-V)	0.09	0.189	0.071	0.08	0.125	0.049	5.505	0.043	0.073	0.048	0.039	0.014	0.073	0.066	0.229	0.048	0.076	0.146
Protection Current (-V)	0.643	5.188	0.597	0.706	0.489	0.84	5.517	0.444	0.907	0.554	1.158	0.31	0.462	1.311	0.852	0.753	1.055	0.649
Instantaneous off Protection (-V)	0.391	0.801	0.335	0.371	0.302	0.457	5.484	0.265	0.436	0.376	0.49	0.219	0.353	0.537	0.443	0.34	0.8	0.454
4 Hour Potential Decay(-V)	0.176	0.062	0.114	0.123	0.132	0.199	5.191	0.106	0.163	0.098	0.151	0.105	0.211	0.088	0.274	0.142	0.43	0.124
Depolarized potential (V)	0.215	0.739	0.221	0.248	0.17	0.258	0.293	0.159	0.273	0.278	0.339	0.114	0.142	0.449	0.169	0.198	0.37	0.33

Local rectifier Unit Cabine NO	LRU 11						LRU 12	LRU 13						
Cap Beam(anode zone)	P21			P22			P23	P24			P25			
DC Output (mA)	320			460			1000	350			350			
Reference Cell NO.	R1	R2	R4	R1	R2	R3	R2	R2	R3	R4	R1	R2	R3	R4
Natural Potential (-V)	0.104	0.022	0.018	0.051	0.067	0.096	0.025	0.163	0.011	0.195	0.176	0.106	0.37	0.319
Protection Current (-V)	0.796	0.858	0.244	0.483	1.446	0.365	1.376	0.44	0.325	0.251	0.356	0.362	0.228	0.292
Instantaneous off Protection (-V)	0.514	0.489	0.172	0.249	0.351	0.291	0.345	0.385	0.267	0.214	0.327	0.249	0.204	0.273
4 Hour Potential Decay(-V)	0.14	0.124	0.058	0.114	0.099	0.127	0.087	0.192	0.182	0.052	0.182	0.094	0.102	0.2
Depolarized potential (V)	0.374	0.365	0.114	0.135	0.252	0.164	0.258	0.193	0.085	0.162	0.145	0.155	0.102	0.073

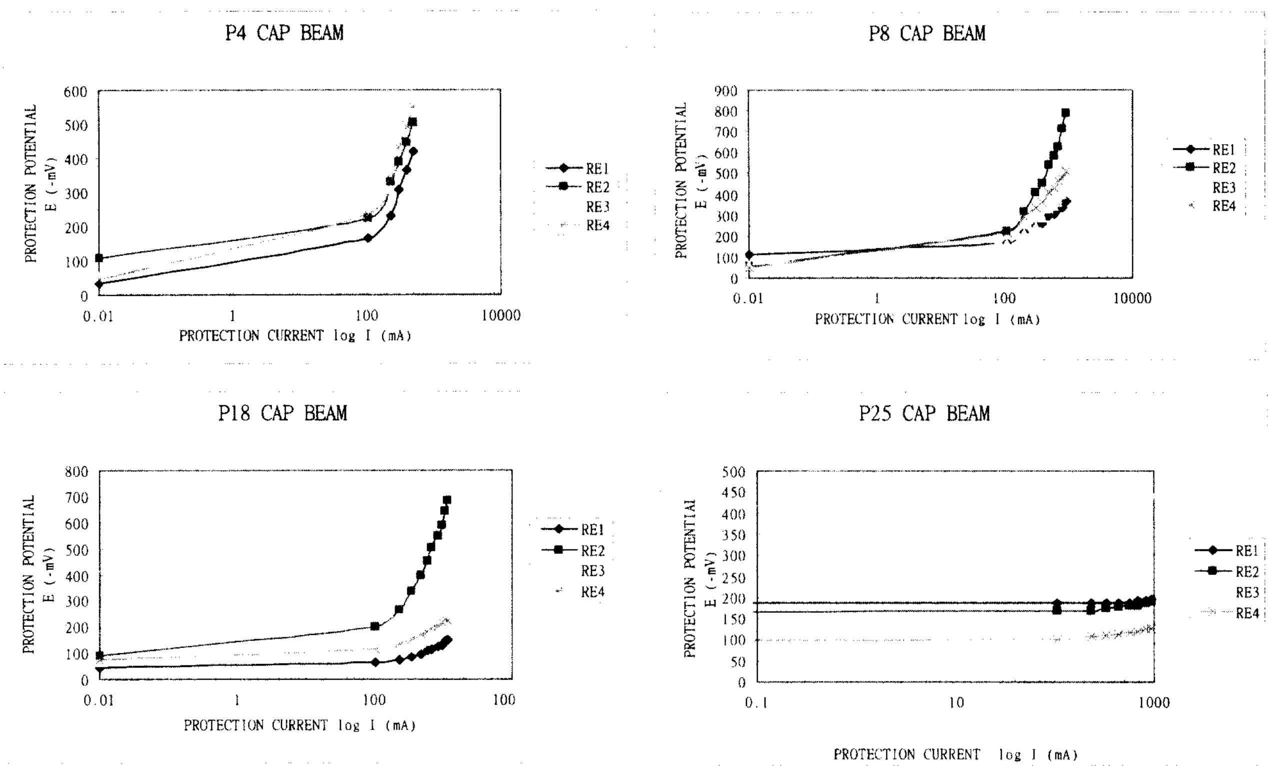

Fig. 3. Current adjustment E-log I curves

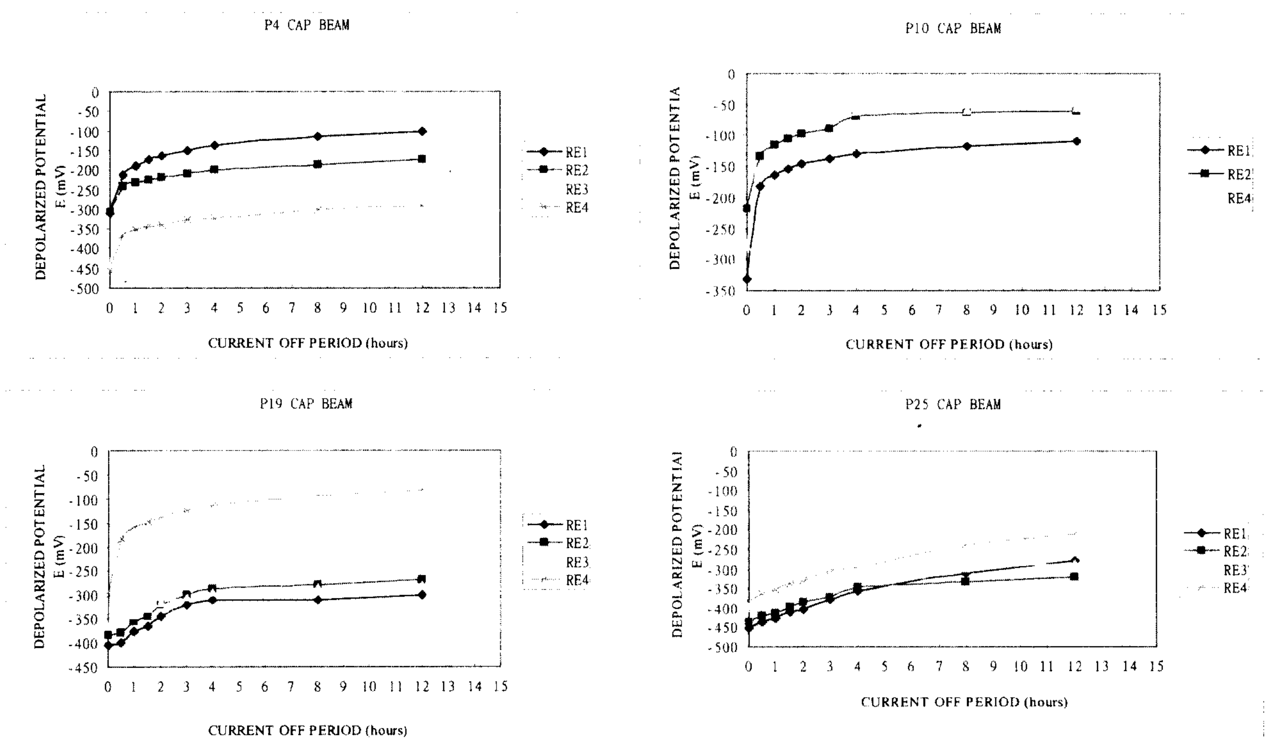

Fig. 4. potential depolarization.curves

is in excess of 4 hours.

4. Conclusions

1) The Shin-da jetty bridge cathodic protection system has successfully managed in a convenient and cost effective way by utilizing far-end telecommunication control system to adjust current and constant assess the status of protection.

2) The reinforcement steel in 23 cap beams are cathodicaly polarized confirmed that the cathodic protection system is in correct functioning condition.

3) The 23 cap beams achieved the 100 mV potential decay criteria.

References

1. NACE RPO 290-90 Concrete Society Technical Report No 36, (1989).
2. NACE RPO 290-90 Concrete Society Technical Report No 37, (1989).
3. R. P. Brown and J. S. Tinnea, "*Report on Design Problems For Cathodic Protection of Reinforced Concrete*", Corrosion 91, The NACE Annual Conference and Corrosion Show, Paper Number 122.
4. L. Bertolini, F. Bolzoni and P. Pedeferri, "Cathodic Protection and Cathodic Prevention in Concrete: Principles and Applications", *Journal of Applied Electrochemistry* **28**, 1321 (1992).