Paper No.
10048

13th Middle East Corrosion Conference & Exhibition

Cathodic Protection Design Considerations for Multiple Well Casings

Pankaj Panchal and Faiyaz Ahmed
Abdulla Fouad Impalloy Ltd., Co.
P.O. Box 257, Dammam
Saudi Arabia
Email: pankaj@afic-cp.com;
faiyaz@afic-cp.com

ABSTRACT

It is a challenging job to design a cathodic protection (CP) system for new well casings with good coating placed in vicinity of already existing bare (non-coated) well casings. Mainly due to considerations for current distribution between the former and the later as the both must be integrated to avoid interference. For a suitable design there are number of controlling factors that need to be taken into account such as well casing resistance remote to earth, back emf, flowline and truckline resistances and negative cable resistance.

This paper presents various scenarios of multiple well casing CP system design.

- Design concept for dual bare well casings.
- Design concept for three or more bare well casings.
- Design concept for existing bare and new coated well casings.
  - ✓ Current distribution by controlling the negative cable resistance.
  - ✓ Current distribution by flow line / trunk line resistance.
- Design variable effecting the current distribution.
- Case study of multiple well casings.

1. INTRODUCTION

Designing of the cathodic protection (CP) system for a new well casing with good coating adjacent to an already existing well casing is challenging, especially when the existing well casing/casings are bare.

One aspect of the corrosion control philosophy adopted for the new oil wells is to provide Fusion Bonded Epoxy (FBE) coats to well casings to minimize the CP current requirements. Use of the FBE coating reduces the required current and thus facilitates the use of a single CP power supply for multiple well casings. Also, for engineering economy and for an integrated and effective cathodic protection system, the new well casing with good coating must be provided with the choice of single CP system.

There is a requirement for proper survey of the existing cathodic protection system of the well casing for creating a suitable design. It needs not to be emphasized that a person having broad experience in cathodic protection surveys is essential.

2. DESIGN APPROACH

The cathodic protection system design for multiple well casings is to be prepared based on the consideration of following essential factors:

- ✓ Project specifications.
- ✓ Client's standards and referenced international standards.
- ✓ Plan drawings.
- ✓ Site survey for existing and proposed CP systems.
- ✓ Survey results.
- ✓ Engineering economy.
- ✓ Interference
- ✓ Control of current for distribution to the wells through the use of negative cable connected to the wells.

3. SITE SURVEY

A thorough study of layout drawings has a great importance for a detailed survey of the CP systems. The site data to be collected during the survey needs to be listed down. Following is the minimum data required to design the cathodic protection system:

- ✓ Existing cathodic protection station locations, rated and operating parameters.
- ✓ Current drawn by existing well casing/casings and flow line / lines by swain meter with current flow directions.
- ✓ Potential difference with polarity between existing casings incase existing casings are two or more.
- ✓ Distance from existing anode bed to new well casings and flow lines.
- ✓ Existing well casing to ground resistance.
- ✓ Existing flow line to ground resistance.
- ✓ Soil resistivity at existing anode bed locations.
- ✓ Soil resistivity at proposed new anode bed locations.
- ✓ Pipe-to-soil potential at nearest test station of existing flow line.

4. DESIGN PARAMETERS

A number of the following experience based field values and measured parameters are to be utilized to facilitate the design:

4.1. Current Requirement for a Bare Oil Well Casing

The CP current required to cathodically protect a bare oil well / water injection well casing is to be 20 to 25 amperes in the onshore coastline area of Arabian Gulf. This criterion has been applied successfully for more than 25 years by operators in Middle – East based on their experience. The CP current requirement for bare oil well / water well injection casings for this design was set at 25 amperes and is sufficient to provide a conservative margin for variance in well completion characteristics.

4.2. Current Requirement for a Coated Oil Well or a Coated Water Injection Well Casing

The CP current required to cathodically protect a FBE coated oil well / water injection well casing is to be 2 to 4 amperes in the onshore coastline area of Arabian Gulf. This criterion has been applied successfully for more than 8 years by operators in Middle – East based on their experience. The CP current requirement for coated oil well / water well injection casings for this design was set at 3 amperes and is sufficient to provide a conservative margin for variance in well completion characteristics.

4.3. Current Requirement for a Bare Water Source Well

A current of 6 amperes is required for the shallow water source wells, primarily to ensure that these well casings would not fail prematurely from interference currents produced by the nearby CP rectifiers. Complete external corrosion protection is not determined to be a high priority on these wells, but a current of 6 amperes is sufficient by the design to ensure acceptable longevity at least from the perspective of external corrosion failures.

4.4. Well Casing Resistance to Ground

The current distribution to the wells will be controlled through the resistance of the negative return paths for the current, the effective resistance to ground of the respective types of well casings also needed to be determined. Field tests must be carried out on typical well types to establish the values to be used for these parameters. The field tests included casing-to-casing resistance substantiated by 3-Pin resistance measurements. Generally, in the onshore coastline area of the Arabian Gulf, it was determined that 0.015 ohms would be used for bare well casings, and 0.07 ohms would be used as the resistance-to-ground of a coated well casing.

4.5. Anode Bed and Well Casing Back EMF

The back emf generated by the half-cell potentials of the anode bed and the well casings is also required to develop a representative equivalent electrical circuit or design.

To develop a representative equivalent electrical circuit for substantiating the design, the back emf appearing as half cell potentials of well casing and anode bed need to be taken into consideration. It was found that the nominal back emf sourced from a polarized well casing was -1.2 volts, and the nominal back emf sourced from a polarized anode bed was +0.8 volts with an overall effect as substantiated by measurements at a number of locations that resulted in an effective cumulative back emf of 2.0 volts, but for design considerations measurements must be taken at selection of representative wells to establish a reasonable approximation for these parameters.

5. DESIGN VARIABLES EFFECTING THE CURRENT DISTRIBUTION

- ✓ Well casing resistance to remote earth

    - ➢ Bare casing
    - ➢ Coated casing

- ✓ Back emf
    - ➢ Bare casing
    - ➢ Coated Casing

- ✓ Flowline and trunkline resistances
    - ➢ Axial resistance (wall thickness, diameter and length of pipe)
    - ➢ Leakage resistance (coating quality, pipe diameter and length)

- ✓ Negative cable resistance
    - ➢ Only control variable in CP design
    - ➢ Size and length of cable

6. DESIGN CONCEPT

6.1. Design Concept for Dual Bare Well Casings

The well casing CP system started in mid 1980's in Middle East generally protected wells far from each other and protected one well and flow line with one CP system. During the early 1990's, with the increase in oil demand the number of oil wells increased in oil field and new wells drilled near the existing oil wells or both new wells drilled close to each other. The new and existing wells were bare. To avoid interference, it was mandatory to provide integrated CP system for both wells. The resistance of well casing to ground was equal or near to equal for both the wells. The provision of isolation joint was not recommended in oil field for flow line and trunk line. The variable resistance in negative cable not recommended due to operations and HSE (Health, Safety and Environment) issues. Current distribution can be controlled by the resistance of negative cable from well to junction box. The location of negative junction box will be selected such a way that both the negative cables coming from the well is equal length and size. If required cable size will be adjusted for current distribution. Refer to Figure 1 for sketch of CP system.

6.2. Design Concept for Three or More Bare Well Casings

During the early 1990's increase in oil demand, number of new wells were drilled near the existing oil wells or new wells drilled close to each other. The new and existing wells were bare. To avoid interference it was mandatory to provide integrated CP system for all the wells. The resistance of well casing to ground fell equal or near to equal for both the wells. The provision of isolation joint was not recommended in oil field for flow line and trunk line. The resistance introduction to the negative cable was not recommended due to operations and HSE issues. The solution for current distribution can be by utilizing the resistance of negative cable from well to junction boxes. The location of negative junction box will be selected in such a way that all the negative cables coming from the well is of equal length and size. If length does not bring desired adjustment the cable size will be adjusted for current distribution. Refer to Figure 2 for sketch of CP system.

6.3. Design Concept for Existing bare and New Coated Well Casings

6.3.1. Current Distribution by Controlling the Negative Cable Resistance

An oil field with existing wells (some being more than 20 years old) distributed throughout is being further developed for crude oil production using a drilling philosophy that places multiple wells on a common drill site location (multi-well drill site) created in 2001 in Middle-East. The new wells for further development are directionally drilled to optimize production characteristics and minimize surface land usage, with typically 5 to 15 wells at each drill site. The well casings pass through the various corrosive formations of the soil strata. The cathodic protection (CP) current requirement of 20 to 25 amperes for a bare well casing in the this field, that was determined during the early 1980's, has been found to be effective in minimizing failures from external corrosion in corrosive formations.

One aspect of the corrosion control philosophy used for the new oil wells in the new development project was to utilize Fusion Bonded Epoxy (FBE) coated well casings to minimize the CP current requirements. Use of the FBE coating reduces the required current to less than 3 amperes per well and facilitates the use of a single CP power supply for each multi-well drill site.

The use of FBE coatings on the new well casings with a single CP power supply for each multi-well drill site provides significant economic and technical merits when compared to bare well casings. Without the FBE coating, most of the multi-well drill sites would require multiple CP power supplies and increase in number of anodes proportional to the increase in the current requirement. Using a simple CP power supply with a single output; and avoiding electrical isolation, resistive control circuitry, and electronic control circuitry presents obvious advantage in equipment cost and maintenance. In addition, there is a reduced probability of deleterious DC interference when only one CP power supply is used and there is electrical continuity between all close proximity well casings.

To avoid interference isolation joint is not recommended. The current requirements for bare and coated wells are different. Bare and coated wells are interconnected by flow line. The casing to ground resistance is different for bare casing to ground and coated casing to ground. The back EMF for coated casing and bare casing is different. The only controllable variable to control the well casing current is negative cable resistance. The length is fixed based on cable route by adjusting cable size the current distribution of bare and coated casings can be controlled. The manual calculation is taking lots of time. It is recommended to use electric circuit software for fast and accurate calculations for complex circuits. Refer to Figure 3 for sketch of CP system.

The case study of this type of design is given below:

6.3.2. Current Distribution by Flow Line and Trunk Line Resistance

CP system using current distribution for the well casing by flow line and trunk line resistance (Satellite System) started in mid 1980's in Middle East. The locations are usually 300 km to 400 km from shoreline of Arabian Gulf. There are typically ten to fifteen similar wells (bare casings) spaced 2 km to 10 km apart and are connected to flow line to a common processing facility. The current requirement is found to be 4 Amp for bare wells. The CP power supply was located at processing facility. There were no isolation joints. The current distribution dictated by resistance in respective flow line resulted in generally poor distribution ranging from 2 to 30 Amps to each casing. Refer to Figure 4.1 for sketch of CP system.

The major re-development project was later initiated with several hundred distributed oil wells and peripheral water injection wells in 2008. All the new wells were coated with FBE coating. The current requirement for coated well is found to be 1 Amp. The CP system was provided with single dedicated power source for existing bare wells and centralized CP system that used trunk line and flow lines to distribute the current to new coated wells.

7. CASE STUDY

This site is located 6 km from Arabian Gulf coastline in eastern region of Saudi Arabia. The site is consisting of following:

- ✓ Four coated oil well casings (new)
- ✓ One bare oil well casing (old)
- ✓ One bare water supply well (shallow and small diameter)
- ✓ Three pipelines connected to the central manifold

Refer Figure 5.1 for arrangement at referred site. The current requirement was as per Table 1 for different type of wells.

Table 1 – Current Requirement

Structure	Design Target (Amps)	Operating Target (Amps)
Coated Casings	3 minimum	2 to 4
Bare Casings	25 minimum	20 to 25
H_2O Wells	<200 mV to nearest well	<200 mV to nearest well

The well casing resistance to remote earth is as below:

- ✓ Bare casing: 0.015 ohms
- ✓ Coated casing: 0.07 ohms
- ✓ Bare water supply casing: 0.05 ohms
- ✓ Coated pipeline: 0.055 ohms

The Back Electo-Motive Force (emf) is as below:

- ✓ Bare casing: 1.17 volts
- ✓ Coated casing: 1.20 volts
- ✓ Bare water supply casing: 1.15 volts
- ✓ Coated pipeline: 1.20 volts

The values of resistance to remote earth and back emf verified through simulation model.

- ✓ Current distribution
- ✓ Potential difference

The values of above fixed resistances, back emf and cable resistances inserted in electronic circuit software. Please refer to Figure 5.2 for results. As per theoretical design model current distribution found as per Table 2.

Table 2 – Current Distribution as per Theoretical Model

Well Designation	Design Target (Amps Min.)	Operating Target (Amps)	Theoretical (Amps)
C1	5	2 to 4	5.118
B1	25	20 to 25	28.64
C2	5	2 to 4	5.311
C3	5	2 to 4	5.208
C4	5	2 to 4	5.147
B2	6	<200 mV (H_2O Well)	9.6A (121 mV)

The commissioning results as listed in tables below.

Table 3 – Commissioning Results – Well Current

Pre-commissioning Form for Multi Well Cathodic Protection Site

Field:			**Site Name:**		
Date:	4-Jan-09	Measurement Taken By (Print Name):			
TR Unit	**Rating**		**Operating Output**		**Total Current Measured at Site**
	30 Volts	100 Amps	10 Volts	38 Amps	57.34 Amp

Well Casing Current Measurement

Well or P/L Number i.e., XYZ-123	Well or Pipeline Type i.e., Bare Oil Well	Min Amps Commission	Amps Returning Thru F/L (1) (Amps F/L with Swain Meter)					Mult 0.6	Amps In Cable(1) (Amps Cable)	Amps Up Casing (=Amps$_{F/L}$ + Amps$_{Cable}$)
			0°	**90°**	**180°**	**270°**	**AVG**	**Actual**		
C1	Coated Oil Well	3	6	6.2	5.8	5.8	5.95	3.39	2.1	5.49
B1	Bare Oil Well	25	16.7	16.6	16.8	16.6	16.7	9.5	22.5	32.00
C2	Coated Oil Well	3	3.5	3.3	2.8	0	2.4	1.37	4.2	5.57
C3	Coated Oil Well	3	5.5	5.6	6.1	6.5	5.93	3.38	2.9	6.28
C4	Coated Oil Well	3	2.4	2.4	2.4	2.6	2.45	1.4	2.4	3.80
B2	Bare Water Supply	6					4.2	4.2		4.20
8" Lateral			5.8	5.8	5.9	6	5.88	3.35		
20" Lateral							14.3	14.3		
4" to Scraper			2.5	2.6	2.8	2.9	2.7	1.54		

Note 1: Current flowing away from well is +ve; current flowing toward well is -ve.

Table 3 – Commissioning Results – Negative JB Current

Negative Junction Box - Current Measurement						
Box Descrip.:	CPJB-05		Box Descrip.:	CPJB-04	Box Descrip.:	
Cable Descrip.	Size	Amps[2]	Cable Descrip.	Amps in Cable	Cable Descrip.	Amps in Cable
C-1	16	2.00	To TR	38		
C-2	16	4.00	B-1	22.5		
C-3	16	3.00	To CPJB-05	15.4		
C-4	16	2.20				
H_2O Well	35	4.20				
Note 2: Current flowing toward rectifier is +ve; current flowing away from rectifier is -ve.						

Potential Difference Between Wells			Notes or Comments
+ve Terminal of Meter to Well Number	-ve Terminal of Meter to Well Number	Potential Difference in millivolts	1 2
C-4	C-3	-4.2	
C-3	C-2	8.9	3
C-2	B-1	-25.6	
B-1	C-1	18.1	4
H_2O Well	C-4	-168	
			5

The theoretical circuit used during design has been modified as per site parameters like back emf, water supply well resistance and foreign current from trunk line system. The results observed are very close to results obtained in commission. Refer to Figure 5.3 for results actual circuit and current flow. Refer to Figure 5.4 for current distributions on site.

The theoretical model achieves adequate current to each well casing without the use of resistors or isolating equipments. The operating data is complicated by high current level supplied by connection of site to trunk line system, but system still works effectively. The comparison of design and operating data shows differences are within tolerable levels and within targets.

8. CONCLUSION

A design with a focus on the negative circuit for current distribution with the use of a single CP power supply can be a cost effective alternative for cathodic protection of well casings for multi-well drill sites. Making use of an external coating system for the well casings enhances the savings (cost of coating included) and increases the number of wells that can be practically protected with a common rectifier.

Representative model development of an equivalent electrical circuit can be used to effectively design a single CP system for protection of a multi-well drill site without the necessity for electrical isolation or electronic current control. The use of widely available commercial electrical engineering software makes optimization of the design both rapid and accurate.

9. ACKNOWLEDGMENTS

The author wish to express their thanks to Mr. Mike McKinzie – Vice President of Abdulla Fouad Holding Co. (AFHC) for permission to present this paper, the entire team of Abdulla Fouad Impalloy Ltd., Co. (AFIC), Cathodic Protection and Coatings Unit of Consulting Service Department of Saudi Aramco for their guidance and Abu Dhabi Company for Onshore Oil Operations (ADCO).

10. REFERENCE

1. NACE Paper "Cathodic Protection Design for Multiple-Well Drill Site" – by Darrell R. Catte and Hussain M. Al-Mahrous of Saudi Aramco, Saudi Arabia.

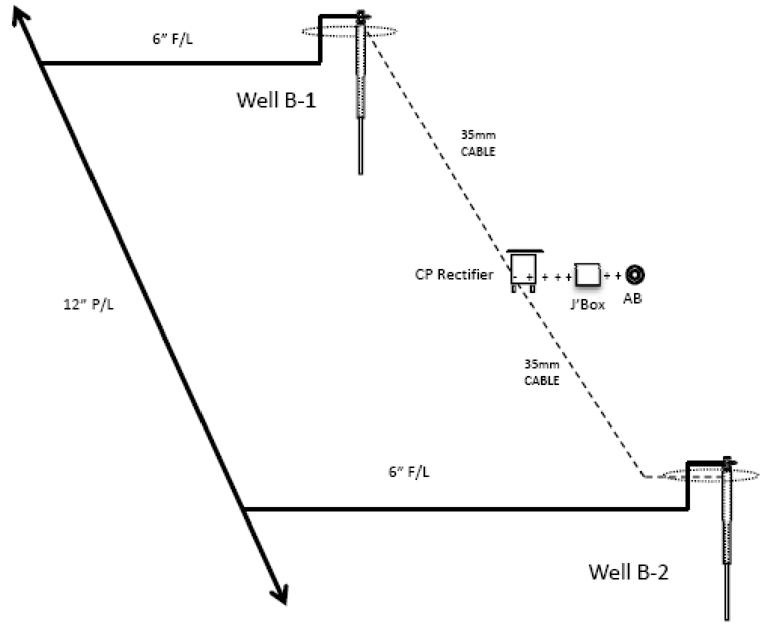

Figure 1 – CP System for Duel Bare Well Casings

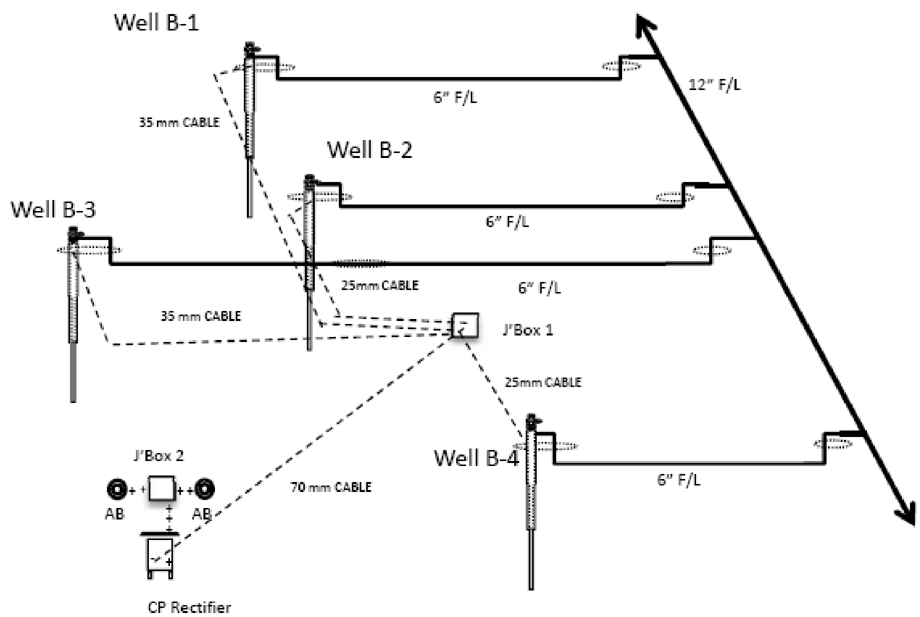

Figure 2 – CP System for Multiple Bare Well Casings

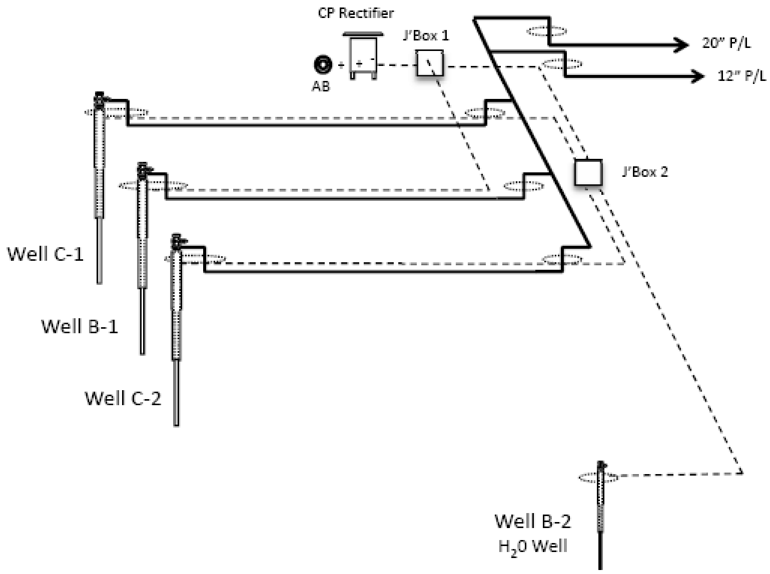

Figure 3 – CP System for Multiple Bare Well Casings

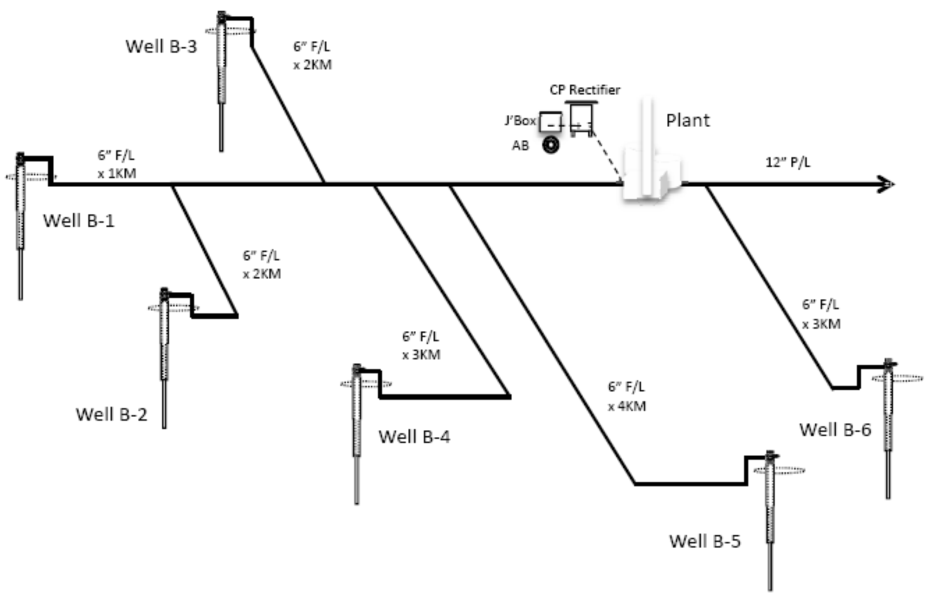

Figure 4.1 – CP System for Multiple Bare Well Casings Current Controlled by Flowline – Poor Current Distribution

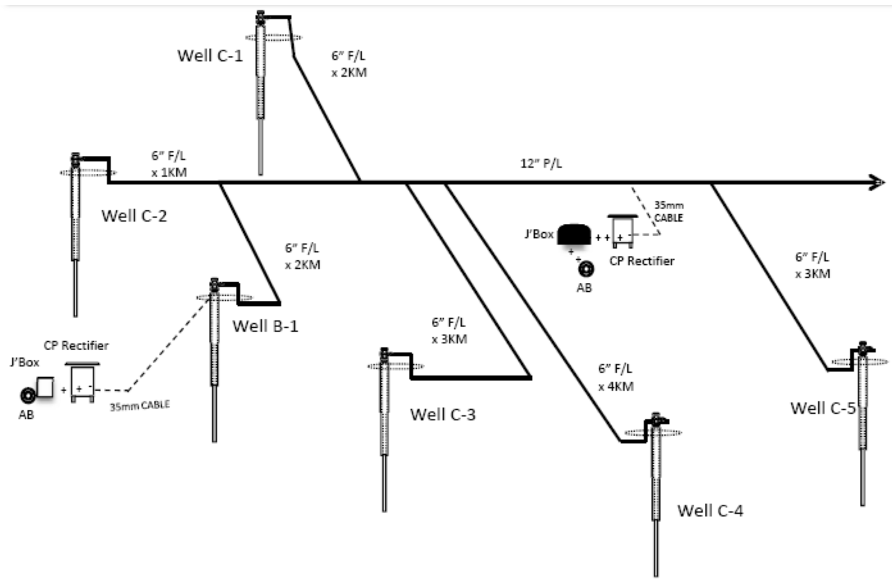

Figure 4.2 – CP System for Multiple Bare and Coated Well Casings Current Controlled by Flowline – Good Current Distribution (Bare well provide with dedicated CP System)

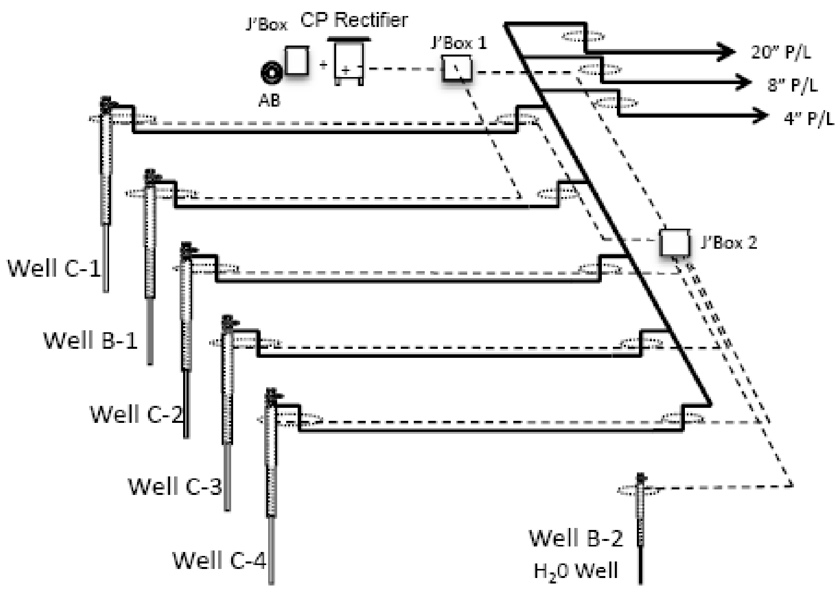

Figure 5.1 – Case Study of CP system for Multiple Bare and Coated Well Casings Site Arrangement

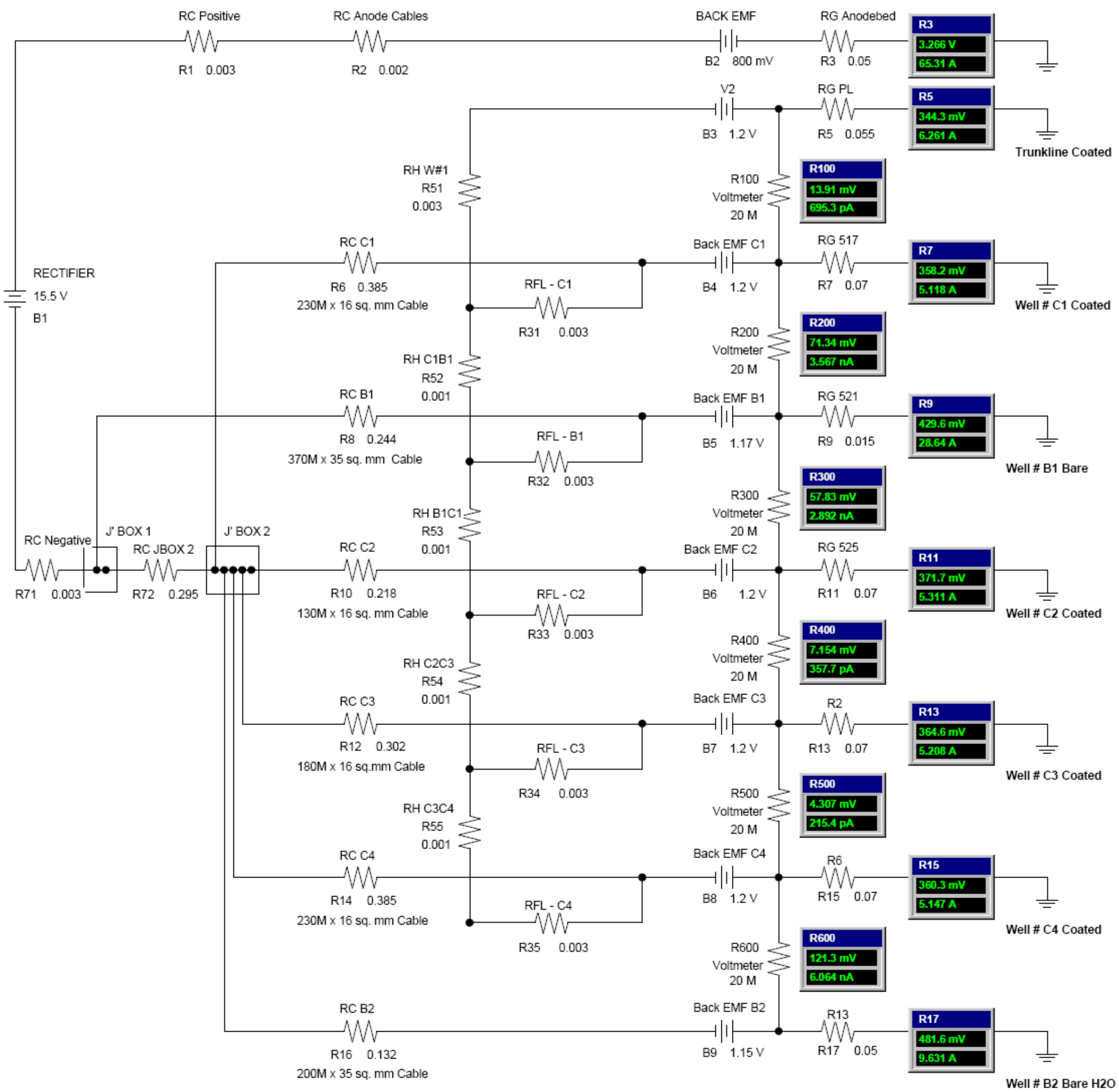

Figure 5.2 – Case Study of CP System for Multiple Bare and Coated Well Casings, Theoritical Design Model

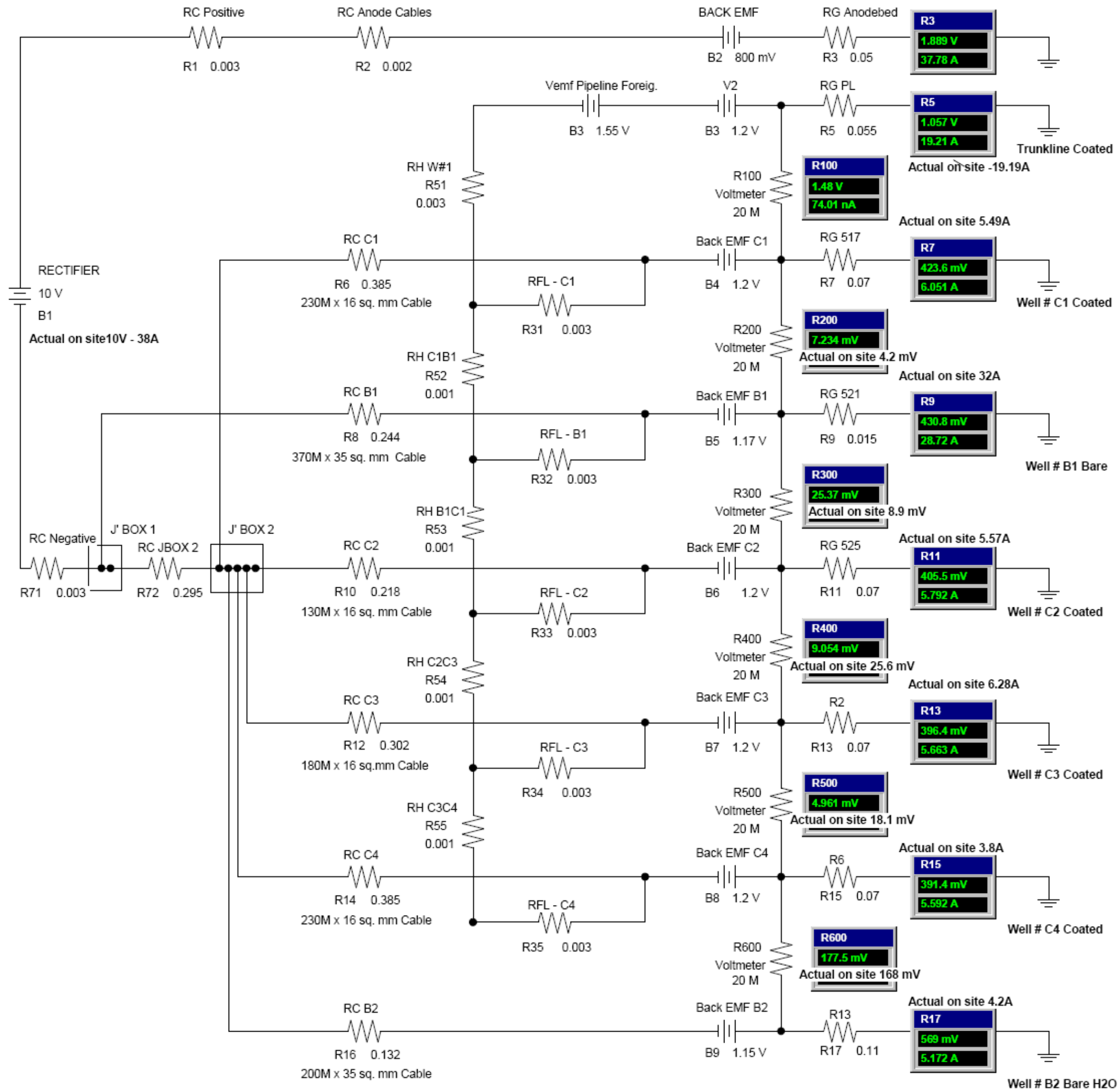

Figure 5.3 – Case Study of CP System for Multiple Bare and Coated Well Casings, Theoritical Design Model (Modified to include current from Trunkline System)

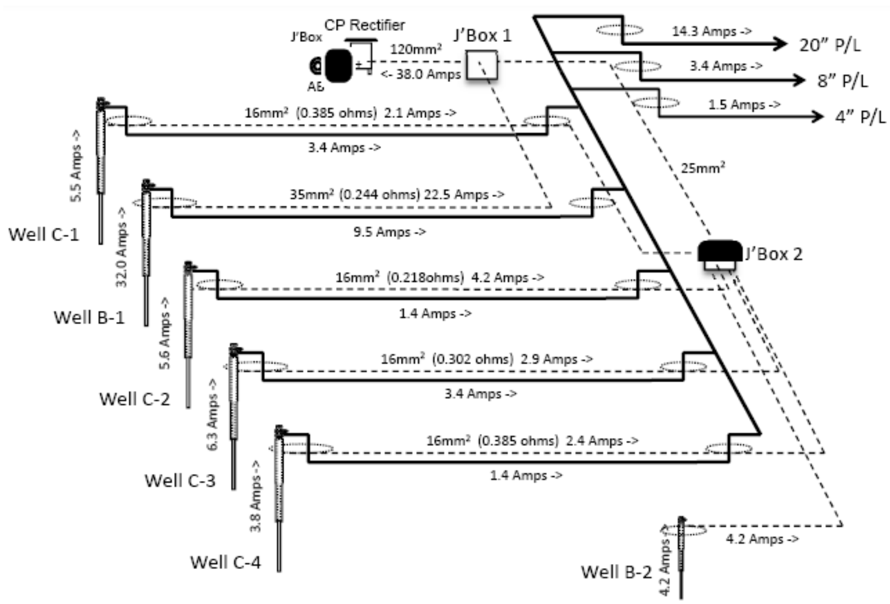

Figure 5.4 – Case Study of CP System for Multiple Bare and Coated Well Casings Current Distribution