MISTI 50.47.29.

AUTONOMOUS POWER SUPPLY OF THE LOCAL SYSTEM FOR CONTROL OF THE FUNCTIONING OF A SEGMENT OF A LONG OBJECT (PIPELINE) AND ITS EXTERNAL LIGHTING ON THE RENEWABLE BASIS

Zulpihar M.[1*], Ilyasov T.[2]

[1]M. Auezov' South-Kazakhstan University, Shymkent. Republic of Kazakhstan
[2]Kazan State Power Engineering University, Kazan, Russia

[*]Corresponding author's e-mail: Murat_zulpihar@mail.ru

ABSTRACT

For the safe operation of gas and oil pipelines in the territory of the Republic of Kazakhstan, in view of the high percentage of paraffin in the extracted oil, the monitoring of the condition of individual sections of the oil pipeline becomes urgent, as well as continuously monitoring the parameters of the transported oil. Such technological objects are of an extended nature, systems for monitoring their functioning must measure, store and transmit over a radio network up to twenty-five important parameters, such as oil temperature, amount of moisture, etc. Remote control systems are highly energy-intensive, and the replacement of batteries in wireless sensor networks containing a large number of these off-grid monitoring systems is time-consuming. In order to increase the battery life of wireless control systems, one option is to design a platform that can store energy from renewable energy sources. When collecting energy from a solar panel, it is possible to carry out the energy storage process in such a way that the maximum power from the panel is generated. This is done by applying algorithms that find the maximum power point of the solar panel. Methods for optimizing the collection of solar energy for powering wireless sensor systems were considered in this work. The algorithm for finding the maximum power point is performed by decrementing the discharge time of the inductive element and comparing the output power of the solar panel before and after these changes. The time stops decreasing if the solar panel's power output is at its maximum. Rebalancing the load current of the solar panel is done periodically by time shifting.

Keywords: monitoring, oil pipeline, hydrate plugs, sensor networks, lighting, storage, maximum power, solar panel.

INTRODUCTION

Kazakhstan possesses huge proven oil and gas reserves. About 10715 km of oil and gas pipelines are used to transport hydrocarbons in the republic. Nevertheless, the Republic of Kazakhstan is currently facing a number of unresolved problems related to the supply of oil to the domestic and international markets. The problems concerning the domestic market are that most of the reserves and the main volumes of oil production are concentrated in the west, while its consumers (large cities and industrial centers) are located in the southeast and industrial north.

Existing pipelines deliver oil to one of three Kazakhstani refineries (in Atyrau, Shymkent and Pavlodar), to southern Russian or Ukrainian refineries, and to the world market.

Analysis of the physicochemical composition of hydrocarbons produced at the field shows that oil and condensate have a fairly high paraffin content. The presence in oil from 3.1% to 12.4% of paraffin, and in condensate 1.9 - 5.6% of paraffin causes a problem associated with the deposition of paraffin in underground and surface processing equipment. To prevent wax deposition, it is necessary to carry out various kinds of measures aimed at preventing and eliminating the consequences of the deposits formation. [1-3].

Another complicating factor in the field is the formation of hydrate plugs. During in-field gathering, transportation of gas and condensate under certain thermodynamic conditions, the effect of throttling of the transported hydrocarbon raw material is objectively created, which leads to the formation of hydrate plugs in the system of transportation and preparation of gas and condensate. The high acid gas content in formation fluids (H_2S - 3.5 %, CO_2 - 5,6 %) also increases the process of hydrate formation. Hydrate plugs greatly complicate the process of collecting and transporting hydrocarbons in the field [4-5].

MATERIALS AND METHODS

Physical conditions, mainly pressure and temperature, change when oil moves through the well bore. As a result of temperature reduction, the ability of oil and condensate to dissolve solid paraffins is reduced. An excess of paraffin that cannot withstand dissolved conditions falls out of solution as solid crystals. The bulk of solid paraffins precipitates in the temperature range from 25 to 0 ° C, reaching a maximum at 15 - 25 ° C. The temperature at which solid paraffin particles appear in oil and condensate, i.e. the temperature of the onset of paraffin crystallization for the Karachaganak field is within 33 - 36 ° C. The composition of paraffin deposits contained in oil and condensate of the Karachaganak field has not been fully investigated, there are some data obtained by the KazNIGRI Institute, which correlate with our experimental data.

RESULTS AND DISCUSSION

From the data (Table 1) it can be seen that the melting point of paraffins separated from oil and condensate does not differ much from each other and are 55 and 53 ° C, respectively.

According to the results of research carried out by Adjip with partners, the following data were obtained:

- oil pour point 15ºC,
- cloud point of oil 44 °C.

The paraffin sediment contains a significant proportion of normal C30 - C40 paraffins.

Table 1. Physical and chemical composition and properties of the Karachaganak oilfield

№	Physical and chemical composition and properties of oil	Indicator
1.	Sulphur , %	0,65
2.	Silica-gel resin , %	6,53
3.	Paraffins , %	3,1 - 12,4
4.	Asphaltenes , %	0,1
5.	Methane-naphthene hydrocarbons, %	75,82
6.	Aromatic hydrocarbon , %	17,55

Table 1 continuation

7.	Oil pour point , ºC	6,0
8.	Paraffin melting temperature , ºC	55,0
9.	Oil density , g/sm^3 at 20 ºC	0,8529
10.	Molecular weight .	246
11.	Kinematic viscosity (at 20 ºC), cCт.	24,34

Control methods associated with the formation and deposition of paraffin on technological equipment and pipelines of the hydrocarbon raw materials' gathering and transport system are divided into the following methods:

1. Mechanical removal of paraffin deposits from the inner surface of pipes and equipment (mechanical scrapers);
2. Thermal control methods;
3.Chemical control methods

Mechanical removal of paraffin deposits is mainly carried out only in pipelines of the infield collection and transportation of oil and condensate.

Heat treatment to remove paraffin deposits involves exposure to various heat transfer fluids and dry steam. Heat treatment for paraffin removal process equipment whose design features do not permit the use of mechanical scrapers. The existing method of operating the process equipment at the field provides for alternate steaming of one of the three technological lines to remove paraffin and non-stop operation of Karachaganak main production complex.

The hydrate crystallization nuclei's formation rate is largely determined by the external pressure and the degree of super cooling of the process.

To determine the hydrates' formation place, it is necessary to know the composition of the gas, the salinity of the water, the equilibrium conditions of the dependence (p-t), i.e. the actual change in pressure and temperature of the gas flow. When the temperature of the gas stream saturated with water vapor falls below the equilibrium temperature, the formation and accumulation of hydrate will occur. The main places of hydrate plugs are the system of field treatment of gas, condensate, as well as the system of infield collection and transport. Having determined the main places of formation and the intensity of hydrate accumulation in the gas collection and treatment systems, it is possible to plot the graphical dependence of the equilibrium temperature of hydrate formation and the actual temperature of the gas flow for timely taking the necessary protective measures. The following methods are used to combat hydrate formation in the field:

1. Drying the gas stream from moisture by sorption or low-temperature separation with a decrease in the dew point.
2. Maintaining the flow pressure below the hydrate formation pressure at a given temperature.
3. Injection of inhibitors against hydrate formation into the gas stream.

The rate of hydrate crystallization nuclei formation is largely determined by the external pressure and the degree of supercooling of the process. With increasing pressure, the rate of formation of crystallization nuclei increases. With an increase in the degree of supercooling, the rate of formation of crystallization nuclei increases sharply, and having reached a certain value at a given pressure, it gradually decreases.

For the trouble-free operation of gas and oil pipelines on the territory of the Republic of Kazakhstan, given the increased percentage of paraffin content in the oil produced, it becomes relevant to monitor the state of individual sections of the pipeline, as well as to continuously monitor the parameters of the oil transported through it. Considering that such technological objects are of an extended nature, the control systems for their functioning must measure, store and transmit over a radio network up to twenty-five important parameters, such as oil temperature, amount of moisture, etc. It is also necessary to provide the emergency lighting of pipeline's each section at night. In the absence of power from the cable lines, the operating time of the wireless control system of the oil pipeline section is limited by the capacity of the batteries [4]. Considering that such remote monitoring systems have a high power consumption, the procedure for replacing batteries in wireless sensor networks containing a large number of such autonomous monitoring systems is time-consuming. In this case, the problem is even more complicated when the wireless sensor network is deployed in unfavorable climatic conditions (desert area). In order to increase the battery life of wireless control systems, one option is to design a platform that can store energy from renewable energy sources. [3], [4], [8], [9], [10]. When collecting energy from a solar panel, it is possible to carry out the energy storage process in such a way that the maximum power from the panel is generated. This is done by applying algorithms that find the maximum power point of the solar panel [11], [12], [16]. These methods increase the efficiency of the charging process. The first method implements the method for finding the maximum power point (MPPT) and the second method provides an effective mechanism for switching the charging of super capacitors when one of them is fully charged and the other is not yet.

Looking at the current-voltage characteristic and the power curve of a typical solar panel (Fig. 1), it can be seen that the solar panel generates maximum power at a certain voltage and current value (Umpp and Impp). The methods currently used to harvest solar energy seek to find the maximum power point tracking (MPPT) of a solar panel. Considering the energy consumption of the autonomous control system, and the amount of energy collected from the solar panel, it is necessary to minimize the power consumption of the circuit performing the MPPT function

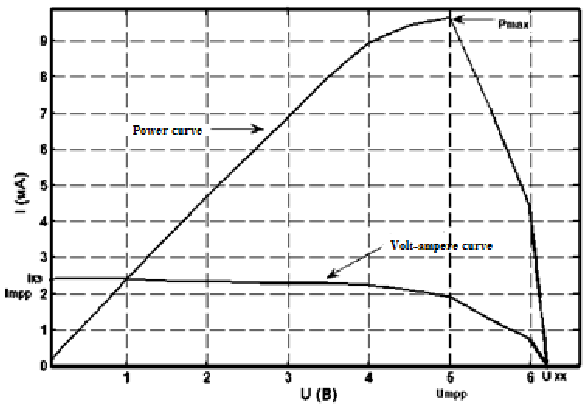

Fig. 1. Curves of power and CVC of the solar panel Kg and K_2 are constants and are used to calculate the values of the optimal voltage and current (V_{mpr} and I_{trr}), respectively.

The first method expresses a linear relationship between the voltage at which the maximum power of the panel is reached (V_{mpr}) and the open circuit voltage of the solar panel (V_{0c}). This method is known as “Fractional open circuit voltage (FOCV)” and can be represented as $V_{mpr} = K_g \setminus 0_c$. The second method is based on a similar principle, however, it expresses a linear relationship between the current at which the maximum power is generated and the panel short-circuit current I_{sc}. This method is called “Fractional Short Circuit Current (FSCC)” and is mathematically expressed as $I_{tr\ p} = K_2 I_{s\ s}$. The third method is called Perturb

& Observation (P&O).

The logic of this method is to periodically "perturb" the operating point of the solar panel by changing its voltage in order to find the point of maximum power. With this method, the power of the solar panel is compared before and after each voltage disturbance. As a result of the voltage disturbance process, if the power of the solar panel increases then it means that the operating point of the panel has moved towards the point of maximum power and the voltage disturbance should continue in this direction. A decrease in the power value of the solar panel after carrying out the voltage disturbance process means that the operating point of the panel has moved away from the point of maximum power..

An algorithm was developed for finding the maximum power point of the solar panel for the tasks of wireless sensor networks in the work presented in [16].

This method is based on the principle of perturbation and observation (P&O). The authors compared the performance of the system with a platform using a diode and as a result of the analysis it was observed that the system that applied optimization algorithms generated an output power up to 1 mW, however, the second platform could not provide power below 10 mW.

Papers [13], [14] and [15] use the FOCV method to find the maximum power point. In work [16] it can be seen that an additional solar panel is designed to measure the open circuit voltage, which allows you to continuously monitor the point of maximum power.

The authors in [10] set themselves the choice of two methods: FOCV and FSCC. To do this, they measured the values of K_1 and K_2. Based on the comparison result, it was observed that the range of changes in K1 is in the range from 0.68 to 0.8 and for K2 it is from 0.25 to 0.68. This work applies the FOCV method based on a narrower range of variation compared to FSCC. To implement the method, a circuit was developed that periodically (at certain specific time intervals) measured the open circuit voltage of the solar panel and stored its value in order to adjust the voltage to the optimal point.

The methods of automatic search for optimum solar panel operation to provide power supply to autonomous station, to control parameters of separate segment of oil pipeline allow to increase the autonomous operation time of accumulator batteries, allow to increase the battery life and reduce the maintenance time with a large number of such control stations.

As a State without maritime borders, Kazakhstan needs a well-developed oil and gas pipeline system. However, the existing pipeline infrastructure cannot meet the growing needs of the republic in the transportation of hydrocarbons to both domestic and international markets in the long term.

Analysis of materials on paraffin and hydrate formation control at the Karachaganak fields shows the following:

1. The starting point of the paraffins crystallization from Karachaganak gas condensate is within 33-36 ºC

2. The bulk of solid paraffins precipitates in the temperature range from 25 ° C to 0 ° C and reaches a maximum at 15 - 25 ° C.

3. On the surface of equipment and pipelines of the Karachaganak field, not only purely paraffinic deposits are formed, but also deposits with the inclusion of hydrates, i.e. hydrate-paraffin deposits.

For effective hydrate control, it is necessary to know the following indicators: a) the amount of moisture contained in the liquid state and condensed in the gas pipeline; b) the actual temperature in the gas pipeline; c) the water content of the gas at the entry and exit points of the inhibitor;

CONCLUSION

Three methods have been considered in this work to optimize the collection of solar energy to power wireless sensor systems. In the first method (FOCV), the voltage at which the maximum power is generated has a linear relationship with the open circuit voltage of the solar panel. In the second method (FSCC), the current at which the maximum power is generated has a linear relationship with the short solar panel current. The third method (P&O) is based on “perturbing” the voltage of the solar panel and observing its power output before and after each change. If the power of the panel increases after each operation, it means that the operating point of the solar panel has moved towards the point of maximum power. When power decreases after each voltage perturbation, this means that the solar panel’s working point has moved away from the maximum power point.

The algorithm for finding the maximum power point is performed by decrementing the discharge time of the inductive element and comparing the output power of the solar panel before and after these changes. The time stops decreasing if the solar panel's power output is at its maximum. Rebalancing the load current of the solar panel is performed periodically by shifting the discharge time of the inductive element by several steps and finding a new optimal point.

REFERENCES

1 Galonskii P.P. Bor’ba s parafinom pri dobiche nefti. Teoriy i praktika. Gostoptehizdat, 1955 g.
2 Batmanov K.B. Батманов К.Б. «Primenenie himicheskih reagentov v neftedobiche// «Neft i gaz», № 5, 2006 g.
3 Brunelli D., Rossi M. Enhancing lifetime of WSN for natural gas leakages detection // Microelectronics Journal. 2014. Vol. 45. No. 12, pp. 1665-1670.
4 Somov A.S., Baranov A.M., Spirjakin D.N., Passerone R., Circuit design and power consumption analysis of wireless gas sensor nodes: one-sensor versus two-sensor approach // IEEE Sensors Journal. 2014. Vol. 14. No.6, pp. 2056-2063.
5 Baranov A.M, Spirjakin D.N, Akbari S., Somov A.S. Passerone R. POCO: Perpetual operation of CO wireless sensor node with hybrid power supply // Sensors & Actuators A: Physical. 2016. Vol. 238, pp. 112-121.
6 Magno M., Boyle D., Brunelli D., O'Flynn B., Popovici E., Benini L. Extended Wireless Monitoring Through Intelligent Hybrid Energy Supply // IEEE Transactions on Industrial Electronics. 2014. Vol. 61. No. 4, pp. 1871-1881.
7 Akbari S. Energy Harvesting for Wireless Sensor Networks Review // Proceedings of the Federated Conference on Computer Science and Information Systems 2014 (FedCSIS), Warsaw, Poland, 2014, pp. 987-992.
8 Weddell A.S., Merrett G.V., Al-Hashimi B.M. Photovoltaic Sample-and-Hold Circuit Enabling MPPT Indoors for Low-Power Systems // IEEE Transactions on Circuits and Systems I: Regular Papers. 2012. Vol. 59. No. 6, pp. 1196-1204.
9 Huynh D.C., Nguyen T.A.T., Dunnigan M.W., Mueller M.A. Maximum power point tracking of solar photovoltaic panels using advanced perturbation and observation algorithm // Proceedings of the IEEE 8th Conference on Industrial Electronics and Applications (ICIEA). Melbourne, Australia, 2013, pp. 864-869.
10 Vullers R.J.M., van Schaijka R., Doms I., Van Hoof C., Mertens R. Micropower Energy Harvesting // Solid-State Electronics. 2009. Vol. 53. No. 7, pp. 684-693.

11 Mathuna C., O’Donnell T., Martinez - Catala R.V., Rohan J., O’Flynn B. Energy Scavenging for Long - Term Deployable Wireless Sensor Networks // Talanta. 2008. Vol. 75. No. 3, pp. 613-623.
12 Alippi C., Galperti C. An Adaptive System for Optimal Solar Energy Harvesting in Wireless Sensor Network Nodes // IEEE Transactions on Circuits and Systems I: Regular Papers. 2008. Vol. 55. No. 6, pp. 1742-1750.
13 Brunelli D., Moser C., Thiele L., Benini L. Design of a Solar-Harvesting Circuit for Batteryless Embedded Systems // IEEE Transactions on Circuits and Systems I: Regular Papers. 2009. Vol. 56. No. 11, pp. 2519-2528.
14 Yu H., Yue Q. Indoor Light Energy Harvesting System for Energy-aware Wireless Sensor Node // Energy Procedia (Proceedings of the International Conference on Future Energy, Environment, and Materials). 2012. Vol. 16. Part B, pp. 1027-1032.