IMPLEMENTATION OF GPS TECHNOLOGY IN PLANNING OVERHEAD POWER LINES

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INTRODUCTION

Route selection and planning represent increasingly difficult tasks since the right of-way for transmission lines is limited and many aspects and interests have to be considered. Route selection and approval depend on the statutory conditions and procedures and always involve iterative studies carried out in the office and surveys in the terrain which consider and evaluate a great variety of alternatives. After definition of the route the longitudinal profile has to be surveyed, identifying all crossings over roads, rivers, railways, buildings and other overhead power lines. The results are evaluated with computer programs to calculate and plot the line profile. The towers are spotted by means of computer programs as well, which take into account the conductor sags under different conditions, the ground clearances, objects crossed by the line, technical data of the available tower family, tower and foundation costs and costs for compensation of landowners. The result is an economical design of a line, which accounts for all the technical and environmental conditions. Line planning forms the basis for material acquisition and line erection. (Siemens (1))

Recently GPS system was enabled for use worldwide and in our region. GPS system is the best invention in the field of orientation in space since the compass was invented. GPS system provides information about current location, velocity of movement and accurate time in allmost all weather conditions. It consists of three segments: space segment (a network of 24 satellites), control segment (ground stations for control and correction of satellites and their signal) and user segment (user and his/hers receiver).

This paper explains how GPS technology helps route selection of overhead power line.

CLASSIFICATION OF THE GPS RECEIVERS ACCORDING TO THEIR USE

GPS technology is useful for a variety of activities, such as: Search and Rescue, Aviation and Nautical navigation, mountain climbing, hunting, camping, fishing, and also for professional use such as surveying, planning overhead power lines and roads, etc. All of the users of GPS technology have unique needs which require different levels of understanding and skill in using this technology.

According to their use GPS receivers are divided in these groups:

- Automotive
- Aviation
- Laptop sensors
- Nautical
- Cell phones with GPS
- Handheld GPS

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- Professional GPS

On the other hand handheld GPS receivers are divided into these groups:

- Basic GPS receivers
- GPS receivers that support mapping
- GPS receivers combined with two-directional radio communication
- Fitness GPS receivers

BASIC FUNCTIONS OF THE HANDHELD GPS RECEIVERS

With the use of the handheld GPS receivers, the user can navigate back to a starting point or other predetermined locations without the use of maps or any other equipment. When used with topographic map, user can navigate to identified locations on the map or take readings from a present or previous location.
At the beginner level, the GPS user is to be able to set-up and initialise the unit and SAVE and GOTO a waypoint. For many users, this is all that they need to do. For a little more advanced user, it is important to understand the coordinate grid systems and to be able to plot and read position coordinates on a map.

Initialising

When a GPS receiver is turned on, it begins to receive signals from all satellites in its view (all in all there are at least 24 operating satellites in the orbit around the World in any time of the day). It takes the receiver a few minutes to identify and lock on to the satellites that will give the best reading of the current location (receiver needs to lock at least 4 satellites). If the receiver is turned on for the first time, or if it has been moved several hundred kilometers since it was last on, it takes more time for the receiver to read the current location. After the receiver reads the location, the current position is presented by the unit (latitude and longitude). Some users need no more than that from the GPS receiver, but the GPS receivers have some additional functions, such as memorizing a specific location and calculating distance from that point and what direction the user must travel to get there. Such "remembered" positions are known as waypoints.

Waypoints

With simple pushing a button (MARK) on the device the user memorizes the current location. Such memorized location is stored in the memory of the device and can be used for calculation of the distance from it, and for guidance how to get back to it (GOTO). Some units record temporary waypoints automatically, allowing the user to follow the same route home without the necessity of manual saving waypoints at all.

Planning a route

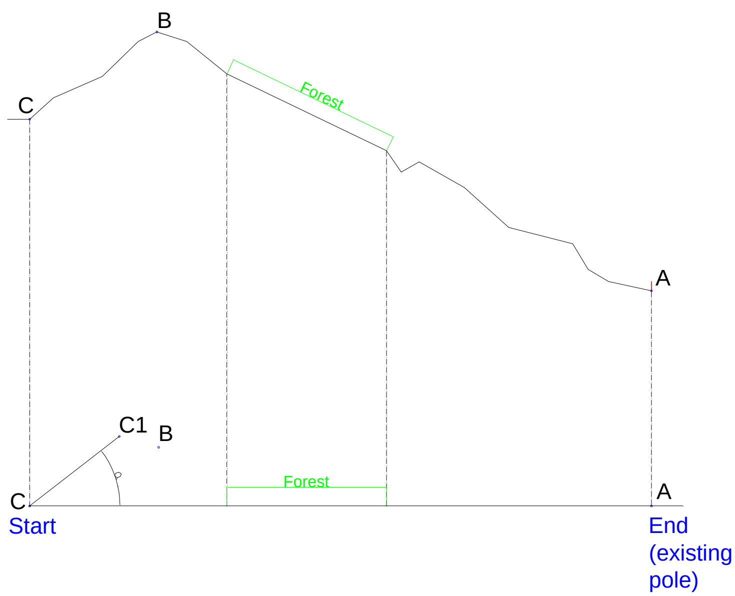
It is not necessary to be at a specific location to mark it as a waypoint. The user can plan out the course on a chart and, using the receiver's keypad, manually or with the use of PC (with special cable for connection) input the latitude and longitude of each course change into the unit as waypoints. The receiver will then not only tell the user what is the location at any given moment, but it will tell the course to steer, taking the user in sequence to the waypoints that have been entered. Such a sequence of waypoints is called route. It is possible to plan a route on the spot, by using memorized waypoints of the GPS that have been marked during moving on the terrain. This function is most useful when a route for the overhead power line is been planed.

Accuracy

Depending of its prize, the accuracy of a GPS receiver is usually around 100 meters for basic devices, accuracy of around 10 meters for DGPS-equipped receiver (Differential GPS is a technique that uses a land-based receiver to measure the error and transmit corrections to the DGPS-equipped receiver) and accuracy of 3 meters for the receivers that support so-called WAAS. The accuracy depends of actual position of the receiver and partially of weather conditions (in cloudy weather accuracy is smaller). Professional GPS receivers on the other hand have accuracy of several centimeters.

USING HANDHELD GPS RECEIVERS FOR PLANNING ROUTE FOR THE OVERHEAD POWER LINES

GPS receivers can be used for planning route for overhead power line. They are very useful at non-regulated terrains (for example mountain terrain), and where length of the line (route) is big and the planner meets numerous obstacles in the route (for example forest, hill, road).
Let's view the following example (Draw. 1.):



Draw. 1: Route of the new power line

We have existing pole of the power line where new line will be attached to the existing one in point A. Point B is the top of the hill, point C is the location of the future substation MV/LV and point C1 is some object visible from point C and point C1 is at least 100m far from point C.
Let's suppose that criteria for choosing the route of the overhead power line that is to be built are: shortest length of the line, avoiding use of angle poles and minimum damage on the forest.
Because of the hill and the forest, there is no optical visibility between points C and A, so the direction of the route of the power line is not obvious.
If previously planner goes to the point A and with the use of GPS marks point A (function mark waypoint and "SAVE waypoint"), afterwards the same is done with the point C, with these saved data it is possible to form a route on the GPS itself, and there is possibility to follow this route at any time. That way, by help of the GPS it is obvious to the planner where the line is to be built, so the attention of the planner is set to the characteristic points: crossing with different objects, crossing with roads, passing over canyons and rivers, passing over rocks, forest, deep valleys, etc. That way the planner can focus on some important issues and have complete picture about problems and obstacles. If there is some big obstacle on the route, planner can mark additional waypoint on the GPS and form a route of three (or more) waypoints. That route will have shape of polyline and it is clear that at the endpoints of that polyline are to be erected corner (angular) poles. That way new route can be inspected and planner is able to make fast conclusion about its feasibility.
The above mentioned usage of the handheld GPS (planner works alone without geometer) is good only during selection of the route, not during final setting of the route. However, the handheld GPS is useful as aid for determination of the direction AC even for the geometer who works with theodolite or total station. Because the absence of visibility between points A and C setting direction AC is not easy, so with the use of handheld GPS point C1 can be marked. Point C1 is visible from the point C where geometer has set his/hers instrument. When geometer is located at the point C, handheld GPS can be set with function GOTO waypoint C1, and that way handheld GPS with the help of the built-in

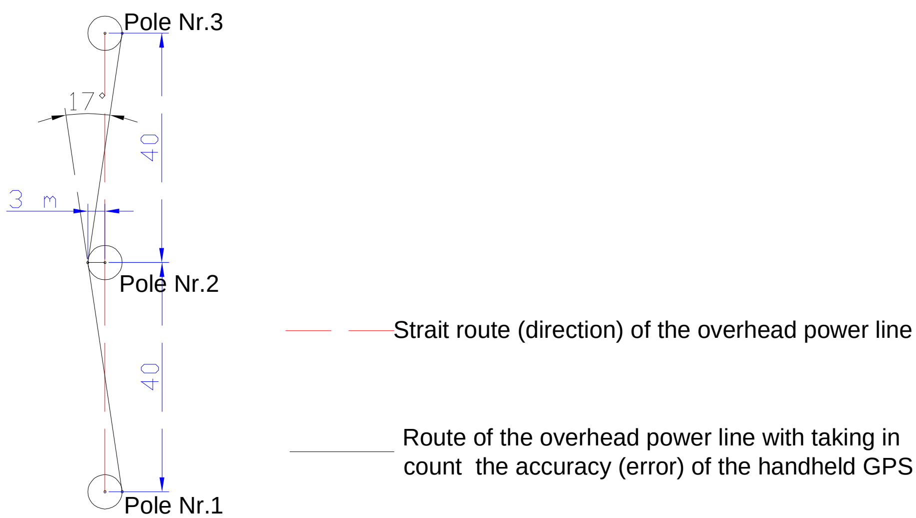
mathematical module gives the angle between the referent point set on the GPS receiver itself (usually true north) and the direction CC1. If in the same manner angle of the direction CA is determined, with subtraction of that two angles the angle which can be used by the geometer for setting (sighting) direction CA is gained.
The author of this text has some experience of working with GPS along with geometer with total station; accuracy of determination of direction can be as good as deviation of 1 meter of point A when distance AC is 1 km. It was mentioned previously that professional GPS devices have accuracy of several centimeters for same situation. The author didn't have an opportunity to work with such instruments.

LIMITATIONS OF THE HANDHELD GPS RECEIVERS RELATED WITH WORK ON THE OVERHEAD LINES. COMMENTARY OF NECESSARY ACCURACY

In order to get a picture what does an accuracy of 3 m (which modern handheld receivers equipped with WAAS correction have) means for constructing overhead power line, we will discuss two examples of deviation of supporting pole from the route of overhead line for 6 m (worst case)(see Draw.2 and 3.). In first example overhead power line is built with cable of type X00/0-A 3x70+71,5 mm^2 1 kV (such cable is well known in the region of Balkans) on concrete poles with length of 9 m set on spans of 40 m (situation that is common in practice). In second example overhead power line of 10(20) kV is built with bare Al/Fe 50/8 mm^2 conductors on concrete poles with length of 12 m set on distances (spans) of 80 m (also situation that is common in practice).

Example 1. Low voltage overhead power line

Situation is given in the drawing number 2.



Draw. 2: Worst case of location of poles when accuracy of the handheld GPS is 3 m. Example with frequently seen situation of overhead low voltage line

Due to the error that handheld GPS brings to a determination of micro-location of the poles (pole spotting), which in good weather conditions can be 3 m, we see from Drawing number 2 that location of Pole number 2 can deviate from route direction up to 6 m. Angle of power line's route declination is 17^o in that case. If we calculate with maximum working tension of cable of 9 daN/mm^2 (only neutral conductor of the cable is tensioned) and if suppose wind pressure of 50 daN/mm^2, we can calculate the force on the top of the pole and compare it with the nominal force of the pole (guaranteed by the constructor of the pole). Because the pole is supporting one, we calculate according to (Sluzben vesnik na Republika Makedonija (Sl. List SFRJ 65/88) (5)) (only case 1a) and 1b), and not case 2a)).
Calculation shows that because of impreciseness of the handheld GPS there will be a force of 233 daN on the top of concrete pole. For use in low voltage overhead lines are allowed poles with nominal

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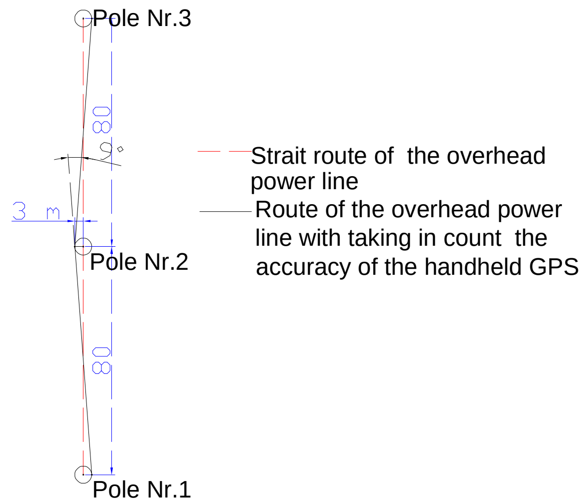
force on the top of 200 daN (JP EPS Direkcija za distribuciju elektricne energije Srbije (6)), so, there are situations where accuracy of the handheld GPS is not good enough for pole spotting.

Example 2. 10(20) kV overhead power line

Situation is given in the drawing number 3.



Draw. 3: Worst case of location of poles when accuracy of the handheld GPS is 3 m. Example with frequently seen situation of 10(20) kV overhead line

We see from drawing number 3 that location of Pole number 2 can deviate from route direction up to 6 m. Angle of power line's route declination is 9^o in that case. If we suppose maximum working tension of conductor is 9 daN/mm^2, if all three conductors are set on top of the pole, if wind pressure is 50 daN/mm^2, we can calculate the force on the top of the pole. Calculation shows that there will be a force of 309 daN on the top of concrete pole because of impreciseness of the handheld GPS. For use in middle voltage overhead lines are allowed poles with nominal force on the top of 250 daN (6), so, the conclusion is the same as in Example 1: there are situations where accuracy of the handheld GPS is not good enough for pole spotting.
If the handheld GPS has built-in barometer, it is possible to determine altitude of current location more precisely (even without built-in barometer some receivers calculate altitude, but not so accurately). Usually changes of altitude are given in steps of one meter by the handheld GPS, so the accuracy of determination of altitude is also for discussion.
Because of the all said above, we can make a conclusion that handheld GPS is useful tool for working with overhead power line, but it can't replace expert's work for surveying. However, if the accuracy of the handheld GPS is to increase during time, say to some 0,5m, probably handheld GPS will be suitable for tower spotting.
As it was said before, the author didn't have an opportunity to work with professional GPS receivers which have bigger accuracy, but it is easy to suppose that bigger accuracy brings problems of different type, such as mobility of the devices and its user or influence of weather conditions.

CONCLUSION

Functions of accurate determination of the location, direction and length from point to point are very suitable for professional use, for example in electrical engineering during determination of route for overhead power line- handheld GPS is programmed to keep the way. Measurement of distances and elevation of the potential pole sites is very simple and fast, so the engineer is free to evaluate more possibilities on site. Such accuracy is good only for deciding route of the overhead line and for sketches, while for determination of line marked out for construction specialist's (geometer) help is needed.

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LIST OF REFERENCES

1. Siemens, 1998, “Power Engineering Guide - Transmission & Distribution ”, “Overhead Power Lines”, "Route selection and tower spotting", page number 9
2. GPS Basics by Don Casey.mht
3. GARMIN Corporation, 2000, "GPS Guide for Beginners-Manual"
4. Garmin Ltd., 2003, "Using a Garmin GPS with paper maps for land navigation"
5. Sluzben vesnik na Republika Makedonija (Sl. List SFRJ 65/88), 1988, "Pravilnik za tehnickite normativi za izgradba na nadzemni elektroenergetski vodovi so nominalen napon od 1 kV do 400 kV"
6. JP EPS Direkcija za distribuciju elektricne energije Srbije, 2001, "Tehnicka preporuka br. 10a", page number 4

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